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Increasing Sorghum Stands in Field Tests by Controlling Thief Ants and Other Insect Pests[1]

C. C. BURKHARDT[2]

ABSTRACT

Treating sorghum seeds with any one of several insecticides or insecticide-fungicide combinations resulted in stand increases ranging from 2 to 571% in field tests during a 3-year study. Stand losses in untreated plots were caused primarily by thief ants, *Solenopsis molesta* Say, while seed-corn beetles, *Agonoderus lecontei* Chaud., and wireworms caused less damage.

The 1958 test plots averaged 63 bushels per acre when seed was treated with an insecticide-fungicide mixture; 46 bushels per acre when treated with an insecticide only; and 12 bushels per acre with fungicide seed treatment only.

Soil treatment with 2 pounds aldrin or heptachlor, or 1½ pounds dieldrin, broadcast and disked in immediately, prior to listing the sorghum seed treated with a fungicide, resulted in excellent stands and higher yields than seed treatments. Soil treatment also gave complete control of chinch bugs.

Sorghum growers for years have had problems in obtaining uniform stands. Frequently either insects or seed-borne and/or soil-borne fungi have caused the problem. Often farmers overseed to help assure a stand. If conditions are ideal, the stand then may be far too thick, or it may be too thick in spots and taken out completely by insects in other spots. A uniform stand of sorghum is important. It alleviates the weed problem and avoids wasted areas brought about by long skips in rows where plants are missing. Higher yields can be obtained when planting the proper recommended rate of seed per acre, properly spaced in a uniform stand. Frequently one or more replantings are necessary.

Sorghum has become increasingly important throughout the United States, and particularly in Kansas and Texas. Nearly 119,669,000 bushels, over one-fifth of the nation's crop, was produced in Kansas in 1957. That was almost four times the average crop for the period 1946 to 1956.

Some seed-attacking insects of sorghum were discussed by Hayes (1920), Bryson (1954) and Burkhardt (1958). The thief ant, *Solenopsis molesta* Say, also commonly known as the kafir ant, is the most injurious pest of planted sorghum.

Burkhardt (1955) reported that experimental tests indicated 3 ounces of wettable powder containing 75% aldrin, or 25% lindane, or 50% heptachlor per 100 pounds of seed prevented the ants from attacking the seeds. Lindane-treated seed, when stored longer than 30 days, caused some reduction in germination.

Srivastava & Bryson (1956) found ant injury was prevented by treating seed with aldrin, Panogen Pa-2, lindane, Panogen Pl-1, Seed Guard, and heptachlor at the rate of 4.5, 7, 4, 2.8, 2.7, and 5 ounces respectively, per 100 pounds of seed. Untreated checks showed more than 50% of the seeds destroyed by the ants.

Much of the work previous to 1956 was conducted in laboratories and insectaries. The results reported in this paper are all from field studies conducted during 1956 through 1958.

MATERIALS AND METHODS.—Seeds of both grain and forage type sorghums were treated during the 3 years of evaluation.

Dieldrin, heptachlor, and lindane were used with and without fungicides in seed treatment studies. Fungicides used included captan, cerasan, and panogen. In some cases the seed was treated first with the fungicide and then with the insecticide but in most cases the seed was treated with commercially prepared fungicide-insecticide combinations. All insecticides and all fungicide-insecticide mixtures were applied to the seed as dry treatments. Seeds were thoroughly treated by mixing in a rotating barrel.

Aldrin, dieldrin, and heptachlor also were used as soil treatments in the rates of actual toxicant per acre indicated under results. Emulsifiable concentrates of these materials were mixed with water and sprayed on the soil with a tractor-mounted sprayer, then disked in shortly after application, and before planting.

Tests usually were located in infested areas known to have thief ants, seed-corn beetles (*Agonoderus lecontei* Chaud.), or other seed-attacking insect pests. Size of plots varied but each treatment generally consisted of more than 1 acre and frequently 3 or 4 acres.

Seeds and soil were examined to determine what insect or insects were involved but no insect counts were attempted. Evaluations were based entirely on stand counts. These were taken late enough that all seedlings, including those with delayed emergence, could be counted. Each sample was taken at random and consisted of the number

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Table 1.—Summary of sorghum seed-treatment field tests for thief ant control in Kansas during 1957.

Test No.[a]	Treatment	Average No. Plants per Replication	Stand Increase by Treatment (%)
	Plainsman Variety		
I	Captan-dieldrin 60-15[b]	60	300
	Untreated	15	—
III	Captan-dieldrin 60-15	298	255
	Untreated	84	—
	Atlas Sorgo Variety		
II	Captan-dieldrin 60-15	139	38
	Cerasan M[c]	117	16
	Untreated	101	—
IV	Dieldrin[d]	291	98
	Untreated	147	—
V	Heptachlor[e]	153	143
	Dieldrin	205	225
	Untreated	63	—
VI	A. Heptachlor	127	140
	Untreated	53	—
	B. Dieldrin	86	207
	Untreated	28	—
VII	Captan-dieldrin 60-15	113	109
	Untreated	54	—

[a] Each test located in different area of State; plant counts based on 6 to 10 replications.
[b] All captan-dieldrin used in 1957 tests was 60-15 (captan 60% and dieldrin 15% by weight) applied at the rate of 2½ ounces of 60-15 per 100 pounds of seed.
[c] Applied at 1 ounce per 100 pounds of seed.
[d] All dieldrin in these tests was 50% wettable powder, applied at rate of 1½ ounces actual toxicant per 100 pounds seed.
[e] All heptachlor in these tests was 50% wettable powder, applied at rate of 1½ ounces actual toxicant per 100 pounds seed.

of plants in 25 feet of row. Such a sample was replicated from 8 to 20 times, depending on available time and assistance. From 1956 to 1958, inclusive, 18 seed-treatment field tests were established, three of which were lost by flooding. Results from the remaining 15 are reported here. Two soil-treatment field tests also were conducted and are discussed under results.

RESULTS AND DISCUSSION.—*1956 Field Tests.*—Thief ants were found destroying Atlas sorghum west of Manhattan, Kansas. Seed treated with 2 ounces of wettable powder containing 50% dieldrin or 1 ounce actual toxicant per 100 pounds of seed resulted in 180% increase in stand in the treated over the untreated plots. Results were taken from 20 random samples (25 feet of row per sample) from each plot. There was an obvious visual difference between the treated and untreated plots, both because of increased stand and increased height (about 1 inch) in the treated plots.

1957 Field Tests.—Results of all the seed-treatment tests, except the sorghum variety tests, are shown in table 1. The insect pests involved in most of these plots were thief ants, with seed-corn beetles to a lesser extent and occasionally a few true wireworms. The results of seven tests show a range of 98 to 225% increase in stands by use of insecticides alone, and from 38 to 300% increase in stands where combination fungicide-insecticide mixtures were used. The only such mixture used in the 1957 test was captan-dieldrin. Results were highly satisfactory. In test II, Cerasan M (N-(ethylmercuri)-*p*-toluenesulfonanilide) at 1 ounce per 100 pounds of seed improved the stand count 16% over untreated seed, but the captan-dieldrin mixture in the same test increased stand by 38% over the untreated.

Seeds for sorghum variety plots, including 14 grain sorghum varieties, were all treated alike with 2½ ounces of captan-dieldrin (60-15) per 100 pounds of seed. Stand increase ranged from 26 to 368% as a result of treatment (table 2). Plants were counted in eight random samples in each of the treated as well as untreated rows of each variety. Percentage increase in stand for each variety was based on these data. There was wide variation in increases from one variety to another, even though the treatment was identical for each. The insects involved were thief ants and some false wireworms. These data suggest the possibility that seeds from some varieties are either more susceptible to attack by certain insects than seeds from other varieties, or they react differently to the same treatment.

1958 Field Tests.—Seed treatment.—Although there was some variation in results, all treatments in the six tests involving seed treatment showed an increase in stand count over the untreated checks (table 3), ranging from 2 to 571%. Tests I through IV indicate satisfactory results with the use of fungicide-insecticide combinations. The check seed was treated with only captan in test V and the addition of heptaclor and dieldrin increased stand counts by 216 and 211%, respectively, over the captan treatment alone. Increases in stand were highly significant in test VI. The differences were accented between treated and untreated seed because of an extremely heavy attack by thief ants, seed-corn beetles, and wireworms. The problem was almost entirely one of insects rather than fungi as indicated by as high as or higher increases from insecticides alone than with fungicide-insecticide mixtures. This is further evidenced by insecticide alone or fungicide-insecticide mixtures resulting in 400 to 571% increase in stand over treatments with

Table 2.—Response of sorghum varieties in terms of stand when all seed was treated with 2½ ounces of captan-dieldrin (60–15) per 100 pounds of seed in Dickinson County, Kansas, 1957.

Variety	No. Plants per Replication[a]		Stand Increase by Treatment (%)
	Untreated	Treated	
R5501	33	49	48
R5590	41	53	30
RS-610	41	52	26
RS-650	45	91	103
RS-7078	17	55	225
Caprock	15	43	197
Redbine 60	8	39	364
Combine 60	26	42	59
Tri 660	41	50	21
Norghum	39	93	135
Midland	16	65	303
Martin	12	58	368
Westland	29	77	164
Plainsman	42	77	82

[a] Average of eight replications.

Table 3.—Summary of 1958 sorghum seed-treatment field tests for thief ant and seed-corn beetle control in Kansas.

Test No.[a]	Variety and Treatment	Average No. Plants per Replication	Stand Increase by Treatment (%)
I	Westland		
	Ortho Dieldrin 60-15[b]	45	19
	Isotox 25 Seed Treater (F)[c]	50	32
	Ortho Heptachlor 25 (F) Treater[d]	54	42
	Ortho Dieldrin 25 (F) Treater[e]	54	42
	Untreated	38	—
II	Plainsman		
	Ortho Dieldrin 60-15	18	29
	Isotox 25 Seed Treater (F)	16	14
	Ortho Heptachlor 25 (F) Treater	17	21
	Ortho Dieldrin 25 (F) Treater	18	29
	Untreated	14	—
III	Atlas Sorgo		
	Ortho Dieldrin 60-15	95	44
	Isotox 25 Seed Treater (F)	67	2
	Ortho heptachlor 25 (F) Treater	76	15
	Untreated	66	—
IV	Atlas Sorgo		
	Ortho Dieldrin 60-15	117	92
	Isotox 25 Seed Treater (F)	152	149
	Ortho Heptachlor 25 (F) Treater	204	234
	Ortho Dieldrin 25 (F)	215	252
	Untreated	61	—
V	Pfisters Hybrid 605S		
	Captan plus heptachlor[f]	60	216
	Captan plus dieldrin[g]	59	211
	Check (captan only)	19	—
VI	Hybrid RS-610		
	Ortho Dieldrin 60-15	35	400
	Isotox 25 Seed Treater (F)	38	443
	Ortho Heptachlor 25 (F) Treater	36	414
	Ortho Dieldrin 25 (F) Treater	38	443
	Lindane only[h]	47	571
	Heptachlor only[h]	38	443
	Dieldrin only[h]	45	543
	Check (Panogen only)[i]	7	—

[a] Each test was located in a different area of the state; average number of plants per replication based on 8 to 15 replications.
[b] 60% captan, 15% dieldrin by weight. Applied at 0.3 ounce actual dieldrin per 100 pounds seed.
[c] 25% lindane and 12.5% captan. Applied 1 ounce lindane per 100 pounds seed except test IV, 2 ounces.
[d] 25% heptachlor, 12.5% captan. Applied at 1 ounce actual heptachlor per 100 pounds seed.
[e] 25% dieldrin, 12.5% captan. Applied at 1 ounce actual dieldrin per 100 pounds seed.
[f] Captan 75 applied at 2⅔ ounces per 100 pounds seed, plus 1 ounce actual heptachlor per 100 pounds seed.
[g] Captan 75 applied at 2⅔ ounces per 100 pounds seed, plus 1 ounce actual dieldrin per 100 pounds seed.
[h] Each applied at rate of 1 ounce actual toxicant per 100 pounds seed.
[i] Panogen 15 at 1½ ounces per 100 pounds of seed.

Panogen (Cyano(methylmercuri)guanidine) only.

Soil Treatments.—Results from two soil treatment tests using aldrin, dieldrin, and heptachlor are recorded in table 4. Although cost of soil treatment was considerably higher than for seed treatment, it was believed that where true wireworms, and perhaps white grubs, were present and where sorghum or corn would be likely to go into the same field two or more consecutive years, soil treatment may be warranted.

Table 4.—Summary of sorghum soil-treatment tests for control of thief ants, seed-corn beetles and wireworms in Kansas tests, 1958.

Test No.	Variety and Treatment	Actual Insecticide per Acre (Lb.)	No. Plants per Replication[a]	Stand Increase by Treatment (%)
I	Westland[b]			
	Aldrin	3	41	141
	Dieldrin	1.5	36	112
	Heptachlor	3	44	159
	Untreated	—	17	—
II	Hybrid RS-610[c]			
	Aldrin	2	43	514
	Dieldrin	1.5	43	514
	Heptachlor	2	42	500
	Check (Panogen only)	—	7	—

[a] Average of 8 to 15 replications.
[b] Seed not treated with a fungicide.
[c] All seed had previously been treated with Panogen 15 at 1½ ounces per 100 pounds of seed.

The 3-pound rate of aldrin and heptachlor per acre with Westland sorghum, germination 89% (test I—table 4), resulted in lower increases in stand than the 2-pound rate of each with the sorghum Hybrid RS-610, germination 87% (test II—table 4). This difference resulted from an extremely heavy soil insect infestation in test II. The data in test II indicate a highly striking increase (500 to 514%) in stands from the use of soil treatment plus Panogen-treated seed, compared with only Panogen-treated seed.

Soil-treatment plots of sorghum alongside of seed-treatment plots showed additional benefits. Plants were darker green and more vigorous in the soil-treatment plots. Both seed- and soil-treatment plots were equally exposed to a migrating chinch bug invasion, moving out of wheat, through a narrow strip of bromegrass lying completely across the end of all plots. Seed-treatment plots were heavily invaded and considerable damage re-

Table 5.—Sorghum yields in a series of seed and soil treatments in one heavily infested field of RS-610 in Kansas, 1958.

Treatment	Ounces Actual/100 Lb. Seed or Lb./A.	Bushels per Acre
Seed treatment		
Ortho Dieldrin 60-15	0.3	62
Isotox 25 Seed Treater (F)	1	64
Ortho Heptachlor 25 (F) Treater	1	60
Ortho Dieldrin 25 (F) Treater	1	67
Lindane only	1	39
Heptachlor only	1	54
Dieldrin only	1	46
Check (Panogen only)	—	12
Soil treatment		
Aldrin	2	79
Dieldrin	1.5	69
Heptachlor	2	70
Check (Panogen only)	—	12

sulted, while soil-treatment plots were free of chinch bugs and their damage. This interesting side benefit should be considered when evaluating the additional cost of soil treatment over seed treatment. Further tests are desirable, however, to study the economy of soil treatment for sorghum.

Increased Yields.—Table 5 shows yield data from seed-treatment and soil-treatment plots in one of the 1958 tests. Seed treatments with fungicide-insecticide mixtures averaged 63 bushels per acre while seed treatments with insecticides alone averaged only 46 bushels per acre. The check plot in which seed was treated with only a fungicide (Panogen), but with no insecticide, yielded the poorest—only 12 bushels per acre.

Yield data were obtained from one other seed-treatment plot in 1958. These yields, although somewhat lower, were generally similar to those recorded in table 5.

CONCLUSIONS.—Results in field tests of treating sorghum seed during the 3-year study have been so outstanding that routine treatment of all sorghum seed after it is cleaned, is henceforth being recommended in Kansas. Treatment may eliminate one or even two replantings. Furthermore, with proper seed treatment, planting rates could be reduced by almost one-third and still result in adequate and uniform stands. Cost of fungicide-insecticide seed treatment is low and has resulted in as much as 443% increase in stands over seed treated only with Panogen, and has resulted in as much as 55 bushels more yield per acre. Soil treatment has increased stands as much as 514% and yields as much as 67 bushels per acre over fungicide treatment only. Soil treatment also gave complete control of chinch bugs.

REFERENCES CITED

Bryson, Harry R. 1954. Chemical control of soil infesting insects. Proc. 9th Ann. Meeting, North Central Branch, Ent. Soc. America, 29–30.

Burkhardt, C. C. 1955. Insect pests of sorghums in Kansas. Kansas Certified Seed Directory, Spring 1955.

Burkhardt, C. C. 1958. Control of insects attacking sorghum. Proc. 13th Ann. Meeting, North Central Branch, Ent. Soc. America, 20–22.

Hayes, Wm. P. 1920. A biological study of *Solenopsis molesta* (Say). Kansas Agric. Expt. Sta. Tech. Bull. 7.

Srivastava, B. K., and H. R. Bryson. 1956. Insecticidal seed treatment for control of the thief ant. Jour. Econ. Ent. 49(3): 329–33.

Factors Affecting Rate of Honeydew Deposition by *Therioaphis maculata* (Buck.) and *Toxoptera graminum* (Rond.)[1]

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ABSTRACT

Various factors affecting the rate of honeydew deposition by the greenbug (*Toxoptera graminum* (Rond.)) and the spotted alfalfa aphid (*Therioaphis maculata* (Buck.)) were studied and the reactions of the two species compared. A method was developed whereby honeydew droplets from one aphid feeding for a 24-hour period on a plant part were caught on the bottom or sides of plastic cages.

The rate of honeydew deposition was affected significantly in both the greenbug and the spotted alfalfa aphid by: (1) changes in temperatures; (2) different plant parts as feeding sites (leaf, stem, petiole); (3) different varieties of plants; and (4) the amount of light reaching the host plant and feeding site.

The following factors were found to affect significantly the rate of honeydew deposition by the greenbug: (1) the area of feeding on a Reno barley leaf; (2) feeding on leaves yellowed by age; (3) reduced moisture to host plant.

Changes in the following factors or conditions did not affect significantly the rate of honeydew deposition by the spotted alfalfa aphid: (1) reduced moisture to host plant or (2) distance of leaves from growing point.

The rate of honeydew deposition on Reno and Dicktoo barley and Pawnee wheat exceeded that found on the alfalfa varieties studied. This implies that the problems resulting from honeydew might be as great on barley and wheat as on alfalfa if it were not for the different methods in cultivation and harvesting time.

The rate of honeydew deposition was found to be influenced almost directly in proportion to the known amount of resistance found in the host plants used. This condition suggests the possibility that the rate of honeydew deposition by aphids may be used to measure the degree of resistance of host plants to aphids, the rate of ingestion of plant material, and to serve as a crude measure of the metabolic activity of the insect.

Honeydew, when deposited in large quantitities, becomes a serious hindrance, especially in harvesting certain crops such as alfalfa and sorghums where cutting or threshing is necessary. Honeydew deposited on plant surfaces also may furnish a substrate for fungus growth and interfere with photosynthesis and normal pollination of flowers. It also may attract other insects, both harmful and beneficial.

Biochemical analyses have been undertaken in an effort to determine the composition of honeydew as a tool in studies of nutritional needs of aphids. But little information is available concerning the factors affecting the rate of honeydew deposition or of methods for determining the rate of excretion.

Michel (1942) in studies with *Lachmus robaris* (L.) on oak measured an average of 5.0 and up to 8.6 milligrams of honeydew per aphid during a 24-hour period. Day &

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Irzykiewicz (1953) estimated from studies with radiophosphorus that *Myzus persicae* (Sulz.) may ingest 35% of its weight in 1 hour. Smith (1937) used the rate of deposition of honeydew to measure the rate of feeding of *Hyalopterus pruni* (Geoff.). Schaefer (1938) found that more honeydew was produced by uncrowded than by crowded aphids. Broadbent (1951) discovered that the rate of excretion was higher in calm air than in wind.

Kirby & Spence (1843), Buckton (1876), Weber (1930), Smith (1937) and Broadbent (1951) described the biology of honeydew deposition in some detail.

Some ideas have been advanced in an attempt to explain by what means the sap is moved into and through the aphid's alimentary tract in such large quantitites. Kennedy & Mittler (1953) suggested that during the feeding process, plant turgor pressure forces large amounts of sap, in the form of honeydew, through the insect's alimentary system. Leonardt (1940) also reported an apparent relationship between osmotic pressure variations in fir trees and the rate of production of honeydew.

MATERIALS AND PROCEDURES.—Varieties of wheat and alfalfa studied were selected because of known variations in degrees of resistance to the greenbug or to the spotted alfalfa aphid.

Reno barley was used to culture the greenbugs. Spotted alfalfa aphids were cultured on susceptible Buffalo alfalfa. Both were preconditioned on test plants for 24 hours prior to beginning of experiments. The only exception was with some of the highly resistant alfalfa clones. On these, aphids usually died within 24 hours so it was necessary to place aphids directly from the culture plant onto the test plant.

Rate of honeydew deposition as used here is the number of honeydew droplets excreted by an individual aphid during a 24-hour period.

Apterous adults of both aphids were used in all of the experiments because they could be distinguished from large nymphs by the exsertion of the cauda which occurs at the fourth molt.

Bison, Dickinson (Resistant), Pawnee and Ponca wheat and Reno, Dicktoo (Resistant) and MO-B475 barley, were used in the experiments with the greenbug. Wheat and barley seedlings were grown either in 16- by 22-inch greenhouse flats, two rows to the flat, or in 4-inch clay pots. The soil was a mixture of six parts black loam, one part sheep manure, and one part sand. The plants were generally 2 to 3 weeks old when the tests were begun.

Cuttings were made from nine different alfalfa plants, *Medicago sativa* L., in the field during November, 1957, and potted in 4-inch clay pots. The potted plants were maintained in the entomology greenhouse during the experiments.

All experiments involving the greenbug, except those on the effect of temperature, were conducted under fluorescent lighting in the basement of an insectary. Average temperature was 75° F. with a relative humidity of 45%.

Experiments with the spotted alfalfa aphid, except the effect of temperature on the rate of honeydew deposition, were conducted in the greenhouse. Temperatures averaged 74° F.; relative humidity averaged approximately 35%. Fluorescent lighting was used in experiments where additional light was required.

FIG. 1.—Aphid honeydew on plastic cages showing differences in patterns of deposition and varying sizes of individual honeydew droplets deposited during a 24-hour period by spotted alfalfa aphids feeding on a B16 (moderately resistant) alfalfa clone. Magnified 10×.

The experiments involving temperature studies were conducted in a 4×6-foot cabinet with thermostatically controlled temperatures. Constant 40-watt standard fluorescent lighting was used in the experiments. Temperatures ranged within ±2° F. of preset temperatures. Humidity varied from 40 to 80% because of different temperatures used.

Hinged $1\times1\frac{1}{4}\times3$-inch plastic boxes were adapted to make aphid cages and to provide an efficient means of collecting the droplets of honeydew (fig. 1). Two holes drilled in the tops of these cages were covered with fine mesh nylon cloth to provide ventilation. The cages were notched with a v-shaped groove in one end, large enough to insert the leaf petiole with a damp cellulose plug for protection of the alfalfa petiole.

In adapting the boxes for caging greenbugs on wheat and barley, a groove was cut in each end of the cage, cellulose plugs placed therein, and the leaf passed completely through the cage. The cages were held in place by fastening them with rubber bands to $\frac{1}{2}$-inch-square wooden stakes. Single aphids were confined in the plastic cages, under varying conditions, or on the plant part being studied, and the number of honeydew droplets recorded at the end of 24-hours.

In the light intensity experiments, the light was regulated by complete coverage of the plant and cages or by

Table 1.—Average honeydew deposition for 24 hours by *Toxoptera graminum* and *Therioaphis maculata* under similar temperature conditions on different host plants under fluorescent lighting.[a]

Variety and Crop	Average Number of Honeydew Droplets at (° F.)												L.S.D.[b]	
	35		45		55		65		75		85			
Therioaphis maculata														
B105 alfalfa clone	4.66	**	11.60	**	18.6	**	27.1	**	33.1	**	38.2		2.65	**
B16 alfalfa clone	1.66	**	5.25	**	9.5	**	16.4	n.s.	18.4	**	21.2		2.246	**
C89 alfalfa clone[c]	0		.08		.3		.25		0		.08		—	
Toxoptera graminum														
Reno barley	9.3	**	12.3	**	18.1	**	28.5	**	40.3	**	32.3		2.365	**
Pawnee wheat	4.3	**	9.0	**	15.1	**	21.8	**	26.9	n.s.	25.4		1.804	**
Dickinson wheat	4.4	**	7.0	**	8.9	**	11.5	**	16.1	n.s.	17.9		1.668	**
Dicktoo barley	4.9	**	7.3	**	10.5	**	13.7	**	16.4	**	13.2		1.833	**

[a] Twelve replications used to obtain averages.
[b] **=significant at the 1% level; n.s. =not significant at any level.
[c] Statistical analysis difficult because of many zero readings.

aluminum foil over the cages leaving the rest of the plant exposed.

In studying reduced moisture to clone B16 and Reno barley as a factor affecting the rate of honeydew deposition, three potted plants were used in each case. One was maintained at near field capacity, one moist, and one with soil dry enough to promote incipient plasmolysis (visible wilting) of the plant. These conditions were maintained for one 24-hour period only because of the rapid senescence of the plant at incipient plasmolysis.

Results.—*Greenbugs on Wheat and Barley.*—There were usually significant increases in the number of honeydew droplets excreted with each 5-degree increase in temperature above 35° F. with both susceptible and resistant wheat and barley varieties. The rate of excretion was higher on barley than on wheat. The highest average was obtained from aphids while feeding on susceptible Reno barley. The average rate of excretion on barley was highest at 75° F. and on wheat at 85° F. There was a significant decline in the rate of excretion of honeydew from aphids on barley above 75° F. (Table 1 and Fig. 2).

The varietal effect (table 2) on honeydew excretion was seen in the significantly lower rate of excretion on Dickinson than on Pawnee, Ponca and Bison wheats. Ponca was almost significantly lower than Pawnee. More honeydew droplets were produced on Reno barley than on Dicktoo or MO-B475 varieties. The rate of excretion on Dicktoo barley was significantly lower than on Reno or MO-B475. No significant difference occurred between Reno and MO-B475.

Reduced light intensity significantly reduced (table 4 and fig. 2) the excretion of honeydew on Pawnee and Dickinson wheat and Reno barley. This occurred whether the entire plant was darkened or when only the part on which the aphid was feeding was darkened. On Dicktoo, significant differences were recorded only when the entire plant was covered.

Reduced moisture to host plant resulted in significant differences (table 2) between rates of excretion between plants in vigorous growing condition, where the soil was moist or wet, and plants where the soil was dry enough to induce incipient plasmolysis of the plant. No significant differences were noted in the rate of excretion of the plant maintained at field capacity and one maintained at point of saturation.

Significantly greater amounts of honeydew were produced by greenbugs on the wheat leaf than on the stem. Likewise, significantly more honeydew was produced on green leaves than on leaves yellowed by age or greenbug feeding. More honeydew was produced by aphids feeding at the base of the leaf than near the tip. Significant differences were recorded between the middle areas of the leaf and the tip area but not between the middle and the base portion.

Spotted Alfalfa Aphid on Alfalfa.—There were usually significant increases in the number of droplets excreted for each 10-degree increase in temperature above 35° F. with both B105, a susceptible clone, and B16, a moderately resistant clone. On clone C89 (resistant) the differences in number of droplets excreted were too small for statistical study. On this clone there was often no excretion at any temperature (table 1 and fig. 3).

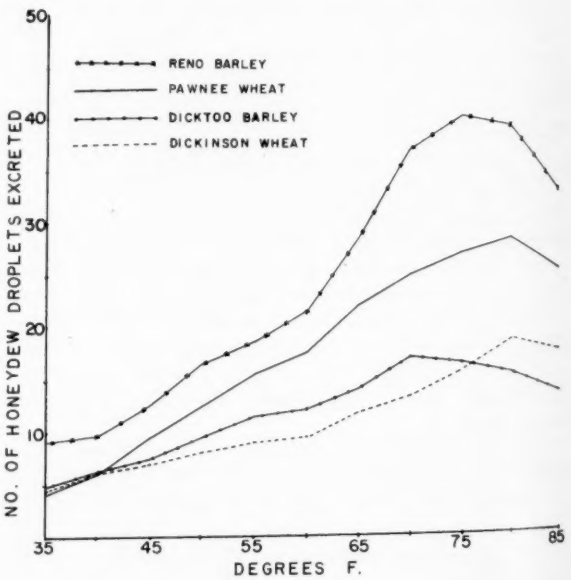

Fig. 2.—Effect of various temperatures on the rate of honeydew deposition by the greenbug while feeding on Reno and Dicktoo barley and Pawnee and Dickinson wheat for a 24-hour period under constant fluorescent lighting.

Table 2.—Effect of various factors and conditions on the deposition of honeydew droplets by *Therioaphis maculata* caged on clone B16; and *Toxoptera graminum* caged on varieties of barley and wheat over a 24-hour period when the contrasting characters were under otherwise similar conditions.

Condition or Factor	L.S.D.	No. of Replications	Average No. of Honeydew Droplets Excreted
Theriaphis maculata on clone B16			
Soil moisture	n.s.	10	
saturated			20.4
damp			16.5
dry (plant wilting)			15.4
Vegetative part of plant	at 5% 2.73	10	
stem			11.46
petiole			9.73
leaf			15.60
Vegetative vs. reproductive tissue on buds or flowers	n.s.	18	
at 71° F.			16.27
at 72° F.			18.50
on non-flowering branch			
at 71° F.			18.30
at 72° F.			19.00
Toxoptera graminum under fluorescent lighting on Reno barley			
Soil moisture	at 1% 5.40	10	
saturated			33.4
damp			28.5
dry			14.4
Vegetative part of plant	at 1% 5.15	10	
stem			29.1
leaf			40.1
Yellowed vs. green leaves	at 1% 1.867	10	
yellowed			5.71
green			16.70
Area of feeding on leaf	at 1% 4.89	10	
Area 1 (base)			19.3
Area 2			17.3
Area 3			21.0
Area 4 (tip)			10.7
Varietal effect	at 5% 10.856	10	
Pawnee wheat			34.0
Bison wheat			30.5
Ponca wheat			25.9
Dickinson wheat			19.0
	at 1% 12.224	10	
Reno barley			45.6
MO-B475 barley			38.5
Dicktoo barley			19.3

Table 3 summarizes the differences occurring among the susceptible, moderately susceptible, and resistant clones used. Significant differences in rate of excretion of honeydew occurred between B105 and 50-1266, two susceptible clones, and B4, B8, B16 and 247, moderately resistant clones. Highly resistant clones 78, C84 and C89 showed highly significant differences from the susceptible and moderately resistant clones. No significant differences in the rate of excretion occurred among any of these highly resistant clones.

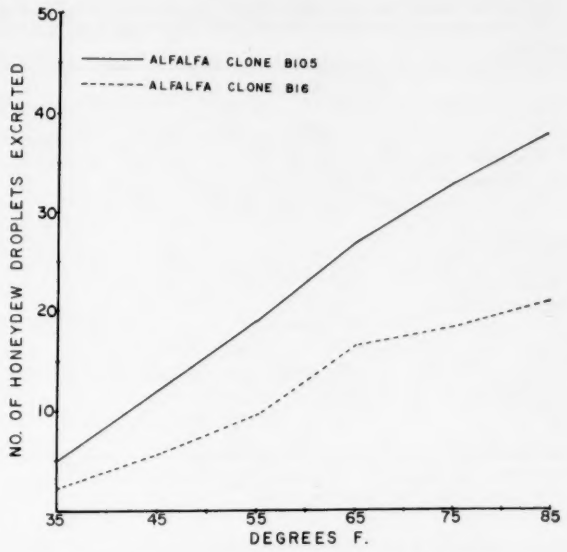

FIG. 3.—Effect of various temperatures on the rate of honeydew deposition by the spotted alfalfa aphid while feeding on alfalfa clones B105 and B16 for a 24-hour period under constant fluorescent lighting.

Reduced light significantly reduced the excretion of honeydew on alfalfa clones B8, B16, B105 and 50-1266. This occurred whether the light to the entire plant was reduced or just the part on which the aphid was feeding. On the highly resistant clone C89 too little excretion occurred to establish a trend (table 4).

No significant differences in excretion were found when the aphids fed on individual leaves from 1 to 24 inches below the growing point of a stem of clone B16 (table 5). Likewise there was no significant difference in excretion whether aphids fed on flowers and buds or on vegetative branches of the plant. Nor did amount of moisture in the soil (table 2) significantly vary excretion. The amount of excretion, however, was higher from leaves and stems than from petioles.

Table 3.—The effect of different alfalfa clones carrying various degrees of resistance as a factor affecting the rate of honeydew deposition by *Therioaphis maculata* feeding for a 24-hour period at an average temperature of 67° F.

Alfalfa Clone	No. of Replications	Average No. of Droplets per Aphid	Clones on Left Significantly Different from[a]							
			50-1266	B4	B8	B16	247	C89	C84	78
B105	15	30.7	n.s.	***	***	***	***	***	***	***
50-1266	24	28.5		***	***	***	***	***	***	***
B4	33	13.2			n.s.	n.s.	n.s.	*	**	**
B8	38	12.2[b]				n.s.	n.s.	n.s.	**	*
B16	27	12.1[b]					n.s.	n.s.	**	*
247	7[c]	10.4						n.s.	n.s.	n.s.
C89	3[c]	2.9							n.s.	n.s.
C84	6[c]	1.7								n.s.
78	4[c]	1.0								

[a] n.s. non significant; *significant at 5% level; **at 1% level; ***at 0.1% level.

[b] The lower average deposition rates for B8 and B16 in this experiment as compared with other experiments with these clones is attributable to the lower temperature and shorter day periods during February 1958.

[c] The low number of replications used to obtain an average number of honeydew droplets excreted per aphid is due to the highly resistant nature of these plants to spotted alfalfa aphid feeding. Many aphids were caged on 247, C89, C84 and 78 but excretion of honeydew occurred only in the number of cages indicated. If zeroes had been included averages would have been much lower.

Table 4.—Reduction in light intensity as a factor affecting the rate of honeydew deposition by *Therioaphis maculata* and *Toxoptera graminum* while feeding on different host plants under similar temperature and light conditions for a 24-hour period.

Variety or Clone	No. of Replications	Average Number of Honeydew Droplets Excreted under			L.S.D. at 1% Level[a]		
		Reduced Light to All of Plant (A)	Reduced Light to Area of Feeding only (B)	Normal Lighting (C)	A&C	B&C	A&B
			Toxoptera graminum				
Reno barley	10	12.5	25.1	39.5	6.09	6.09	6.09
Dicktoo barley	10	8.5	16.2	16.9	3.88	3.88	3.88
Pawnee wheat	10	14.5	21.2	26.9	5.64	5.64	5.64
Dickinson wheat	10	7.8	12.9	16.7	2.77	2.77	2.77
			Therioaphis maculata				
C89	10	0.3	0	0.4	—[b]	—	—
B16	10	3.1	10.2	19.0	4.52	3.57	7.02
50-1266	10	19.3	17.3	30.9	9.12	4.78	n.s.[c]
B105	21	11.2	—	31.4	8.20	—	—
B8	10	2.0	—	11.8	5.60	—	—

[a] All three columns analyzed together under *T. graminum* thus L.S.D. between the three columns are the same.
[b] Too many zeroes for statistical analysis.
[c] Non-significant at any level.

DISCUSSION.—The results were quite consistent. Some random variation in the size of droplets appeared to be related to the size of the individual and not consistently to the conditions being studied. This supposition was further confirmed in studies with age of the aphid as a factor affecting the rate of honeydew deposition, but is not reported because of complications encountered as a result of molting. Molting and reproduction both were found to reduce rate of honeydew excretion.

Excretion of honeydew increased with increased temperature in both species of aphids. The rate of excretion of the spotted alfalfa aphid was still increasing at temperatures up to 85° F. The decline in rate of excretion by the greenbug above 80° F. in wheat and above 75° F. in barley indicates that higher temperatures tend to depress significantly the rate of honeydew production in that insect. This reduction is probably related to the effect of higher temperature on the biology of the greenbug in that it tends to reduce the metabolic activity; or the temperature may be responsible for physiological changes in the plant which might reduce the plant sap available to the aphid. This difference in reaction to higher temperatures between the greenbug and spotted alfalfa aphid is apparently a species characteristic and bears out known observations on the aphids in the field.

The largest amount of honeydew was produced by aphids feeding on barley, and almost as much was produced on Pawnee wheat as on the susceptible alfalfa clones. This is significant in that honeydew would probably be a problem on infested cereal crops if it were not for the differences in time and methods of harvesting.

The significant reductions in rate of excretion associated with reduced light intensity may be related to the effect on the biology of the aphid or on the physiology of the host plant but most likely to a combination of the two.

Excretion of white granular honeydew droplets were noted under conditions of reduced light and deficient moisture to host plant and where leaves were in a yellowed condition because of destruction of chlorophyll. A test for starch in these droplets gave negative results but it appears that the relationship may be in the starch-to-sugar conversion in the plant in absence of photosynthesis rather than in adverse effects on the physiology of the aphid. Reduced light apparently affects spotted alfalfa aphids more than greenbugs as is evident by the greater decline in the deposition rate of honeydew recorded on alfalfa.

Contrasting results in rate of honeydew deposition as affected by available moisture to host plant were recorded between the greenbug and spotted alfalfa aphid. No significant differences were recorded under different conditions with spotted alfalfa aphid on alfalfa. The reverse was true with greenbug on wheat except for one instance (table 2). Results on wheat indicate a possible relationship to theories advanced by Kennedy & Mittler (1953), and Mittler (1957). The contrasting results indicate a need for additional study to throw further light on the reason for the difference in the two aphids. At present it is impossible to determine if the sap flow through the insect is the result of turgor pressure or the use of the pharyngeal sucking pump or both.

Table 5.—The distance of leaves from growing point as a factor affecting the rate of honeydew deposition by *Therioaphis maculata*, for a 24-hour period on clone B16 alfalfa, under natural greenhouse lighting and at an average temperature of 74° F.[a]

Distance from Growing Point (In.)										
1	3	6	8	12	15	17	20	22	24	L.S.D.
15.1	15.0	15.0	12.3	19.1	15.2	16.3	19.6	19.1	17.6	n.s.

[a] Eight replications.

The lack of significant differences in the rates of honeydew deposition by the spotted alfalfa aphid while feeding on buds, flowers, and leaves of a B16 alfalfa clone and the lack of differences while feeding on leaves of a flowering plant as opposed to leaves of a non-flowering plant, strongly indicate that the changes in the physiology of the alfalfa plant before and during the period of flowering have no significant effect on the rate of honeydew deposition by this aphid.

The differences in the rate of excretion varied considerably among the different varieties of wheat and barley and with the several clones of alfalfa used. The rate of deposition of honeydew was correlated very closely with the known degree of resistance of these varieties and clones. In work not reported, various F_4 hybrid lines of wheat involving crosses between resistant and susceptible parents were tested. Results indicated that a relationship may exist in the excretion rate of the greenbug between the F_4 lines and the individual parents. Further work is being conducted at present to throw additional light on the possible relationship between resistance and the rate and chemical composition of honeydew excretion.

The fact that honeydew deposition was found to be influenced almost directly in proportion to known degree of resistance found in the host plants used, suggests the possibility that the rate of honeydew deposition by aphids may be used to measure the degree of resistance of host plants to aphids, the rate of ingestion of plant material, and in addition, serve as a crude measure of the metabolic activity of the insect.

REFERENCES CITED

Broadbent, L. 1951. Aphid excretion. Proc. Roy. Ent. Soc. London (A) **26**(Pts. 7–9): 97–103.

Buckton, G. B. 1876. Monograph of the British Aphides. Vol. 1. Ray Society. 350 p. London.

Day, M. F., and H. Irzykiewicz. 1953. Feeding behavior of the aphids *Myzus persicae* and *Brevicoryne brassicae*, studies with radio-phosphorus. Australian Jour. Biol. Sci. **6**: 98–108.

Kennedy, J. S., and T. E. Mittler. 1953. A method of obtaining phloem sap via the mouthparts of aphids. Nature **171**: 528.

Kirby, William, and W. Spence. 1843. An introduction to Entomology. 6th ed. Vol. **4**. London. 633 p.

Leonardt, H. 1940. Beitrage zur Kenntnis der Lachniden der wichtigsten Tannenhonigtauerzenger. Zeitschr. angew. Ent. **27**: 208–72.

Michel, F. 1942. Beitrage zur Kenntnis von *Lachmus* (*Pterochloris*) *robaris* L., einer wichtigen Honegtonezengerin on der Eiche. Zeitschr. angew. Ent. **29**: 243–81.

Mittler, T. E. 1957. Studies on the feeding and nutrition of *Tuberolachnus salignus* (Gmelin) (Homoptera, Aphididae). Jour. Exptl. Biol. **34**: 334–41.

Schaefer, C. W. 1938. Physiological conditions which produce wing development in the pea aphid. Jour. Agric. Res. **57**: 825–41.

Smith, L. M. 1937. Growth, reproduction, feeding and wing development of the mealy plum aphid in relation to climatic factors. Jour. Agric. Res. **54**: 345–67.

Weber, H. 1930. Biologie der Hemipteren. Berlin. J. Springer. 531 p.

Two New Phosphate-Oil Combinations for Scale Control on Deciduous Fruit Trees in the Dormant Period

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ABSTRACT

Ethion-oil and Phostex® (a mixture of bis(dialkyloxyphosphinothioyl) disulfides)-oil sprays applied during the dormant period have given excellent control of San Jose scale, *Aspidiotus perniciosus* Comst.; olive scale, *Parlatoria oleae* (Colvée); European fruit lecanium, *Lecanium corni* Bouché; and frosted scale, *L. pruinosum* Coq. Trials conducted over a 2-year period indicate that ethion-oil and Phostex-oil sprays provide control equal or superior to that obtained with standard materials with less possibility of tree injury. All the experimental tests were conducted on deciduous trees in California. The optimum toxicant to oil ratios are discussed, and minimum dosages for satisfactory control are given. Ethion-oil and Phostex-oil mixtures are compatible with basic zinc sulphate, zinc carbamate, and fixed copper compounds. Ethion-oil mixtures also have been combined with lime-sulfur and sodium polysulphide whereas Phostex-oil is not compatible with these two materials.

Ethion-oil and Phostex®(a mixture of bis(dialkyloxyphosphinothioyl)disulphides)-oil sprays applied during the winter months have given excellent control of San Jose scale, *Aspidiotus perniciosus* Comst.; olive scale, *Parlatoria oleae* (Colvée); European fruit lecanium, *Lecanium corni* Bouché; and frosted scale, *L. pruinosum* Coq.

The use of dormant spray applications for the control of scale insects has long been an accepted practice on the west coast. Smith (1897) used crude petroleum as an insecticide for the control of armored scales. Quayle (1943) stated that lime-sulfur was first used as a scalicide in California in 1880, and Howard (1898) noted the use of lime-sulfur as a dormant control for San Jose scale. Quaintance (1915) and Weldon (1918) mentioned the use of emulsifiable type oils as dormant sprays for San Jose scale control. The use of 3 to 5 gallons of dormant oil per 100 gal-

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lons of water applied as a full coverage spray during the dormant period has become one of the most widely accepted scale control measures.

Experience has shown that certain species of scales are more easily controlled than others. Armored scales are, in general, more difficult to control than the soft or unarmored scales. Within the armored scale group, olive scale is more difficult to control than San Jose scale. Consequently the amount of pesticide necessary for each species must be determined independently.

Control measures now generally accepted for the control of soft scales include either dormant sprays of 3 to 5 gallons of dormant oil or summer applications of parathion timed to control the hatching nymphs. In control measures aimed at the San Jose scale, dormant applications have so far proven to be more effective than sprays applied at other times. Three to five gallons of dormant oil is widely accepted as a control measure for this insect. Excellent control has also been obtained with parathion-oil sprays. The standard control measures now employed against the olive scale are either dormant sprays of parathion plus dormant oil or spring sprays of parathion and light oil. The spring sprays are timed to control the hatching nymphs.

Phosphate insecticides, as additives to oil sprays, are becoming widely used in the western fruit-growing regions. Available data show that these combinations provide control equal or superior to the straight oil sprays. Since less oil is required, the possibility of tree injury due to excess oil deposit is reduced. Phosphate-oil sprays may also provide control of mite and aphid eggs during the dormant and delayed dormant periods according to materials selected. The optimum ratio of oil and toxicant necessary for maximum control of each scale species must be determined for each material.

Excellent results have been obtained against soft scales during the dormant period with a toxicant plus 2 gallons of oil per 100 gallons of water. Limited information indicates promising results with even less oil. Field trials for San Jose scale control have shown that a minimum of 2 gallons of dormant oil per 100 gallons of water is needed where a toxicant is included. The optimum oil-toxicant relationship for olive scale control has also been established. A minimum of 3 gallons of dormant oil per 100 gallons of water plus toxicant is required for satisfactory control of this scale.

PROCEDURE.—All trials were performed in California on deciduous trees during the dormant period. Materials involved were applied under actual field conditions by commercial spray equipment available at the individual locations. Every attempt was made to insure thorough spray coverage at all times. Each plot was approximately 1 acre in size and individual plots were not replicated.

Samplings for European fruit lecanium and frosted scales were taken from wood developed during the previous year. Five infested twigs, each 6 inches long, were collected at random from each of 10 trees per plot. These samples were collected for evaluation approximately 1 month after treatment. All scales present were examined and the numbers of dead and live scales were recorded. Five hundred to 1,000 scales per plot were examined. In every case, untreated trees were available for direct comparison.

The results of the San Jose scale experiments conducted during 1956–57 were evaluated by counting the total numbers of live and dead scales on the basal 2 inches of infested second-year twigs. Three replicates of 10 twigs each were examined from each plot. In the 1957–58 trials, bark strips ($\frac{1}{2}$ by 2 inches) rather than twigs were sampled and used to evaluate the control. Two strips of bark from each of 10 trees selected at random from each plot were examined. Counts were made approximately 2 months after treatment. The total numbers of scales examined for each plot varied from 2,000 to 5,000.

Results obtained with dormant applications for olive scale control were determined during the following spring. Five infested twigs (6 inches long) and 2 bark strips ($\frac{1}{2}$ by 2 inches) were taken at random from each of 10 trees per plot. Five hundred to 1,000 female scales per plot were examined.

Chemicals employed in all trials have been designated in the tables as concentrates (C), toxicants dissolved in dormant oil (viscosity-SSU 120 at 100° F., UR-80) (TO), and wettable powders (WP). The numbers associated with the (C) and (TO) formulation designations refer to the pounds of active ingredient per gallon, while the (WP) designation refers to the pounds of active ingredient per pound of formulated material. Where concentrates and wettable powders were used in combination with dormant oil, the oil used was a standard commercial product.

RESULTS AND DISCUSSION.—The data in the tables show the results obtained against the various scale species studied. Data pertaining to each species have been grouped together into single tables. The actual number of scales counted for each individual plot have been omitted, and only percentages of dead scale have been included. In this way it has been possible to put all the data available relative to the effectiveness of the different materials against the specific scale species into single tables. All rates given in the following discussion represent pounds of actual toxicant or gallons of dormant oil per 100 gallons of finished spray.

Table 1 summarizes the results of dormant applications of ethion-oil and Phostex-oil sprays for the control of European fruit lecanium and frosted scales. Where mixed populations were present, the percentages of dead scales listed in the table were determined without segregating individual species.

The control obtained with ethion at rates of 0.16 to 0.5 pounds and oil at 1 to 2 gallons was excellent in all trials (1–7). Although only one trial was conducted with oil at the 1 gallon level, it appeared that this spray provided adequate control. Further experimentation, however, should be conducted to confirm this rate.

Four trials involving Phostex were also included. A combination of 0.65 pounds of Phostex and 1 gallon of oil provided only fair control of these scales (trial 8). When the rate of Phostex was increased to 1.2 pounds and the oil increased to 2 gallons, the control was excellent (trials 9–12).

Also included in table 1 is a trial (13) which involved the use of dormant oil at 3 gallons. This spray provided excellent soft scale control.

Table 2 summarizes data obtained with ethion-oil and Phostex-oil sprays for the control of San Jose scale. The initial work (trials 1 to 5) was carried out at low rates of

Table 1.—Results of dormant sprays against European fruit lecanium and frosted scale on deciduous trees in California. 1957–58.

Trial No.	Phosphate Toxicant	Pounds Actual Toxicant/100 Gal. Water	Gal. Dormant Oil/100 Gal. Water	Date Applied	Location	Crop	Per Cent Dead Scale Posttreatment	
							Untreated	Treated
1	Ethion 5.0 (C)	0.16	1.0	1- 4-58	Healdsburg	Prune	21.5	100.0[a,b]
2	Ethion 5.0 (C)	0.32	2.0	2-21-58	Almaden	Prune	32.3	99.6[b]
3	Ethion 5.0 (C)	0.32	2.0	3- 6-58	Gilroy	Prune	17.0	100.0[a]
4	Ethion .16 (TO)	0.32	2.0	12-11-57	Suisun	Peach	17.0	99.5[a]
5	Ethion 5.0 (C)	0.32	2.0	12-30-57	Suisun	Apricot	24.4	100.0[a]
6	Ethion 5.0 (C)	0.50	2.0	12-11-57	Suisun	Peach	17.0	99.4[a]
7	Ethion 5.0 (C)	0.50	2.0	12-30-57	Suisun	Apricot	24.4	100.0[a]
8	Phostex 8.0 (C)	0.65	1.0	1- 4-58	Healdsburg	Prune	21.5	90.0[a,b]
9	Phostex 8.0 (C)	1.2	2.0	2-21-58	Almaden	Prune	32.3	99.9[b]
10	Phostex 8.0 (C)	1.2	2.0	3- 6-58	Gilroy	Prune	17.0	97.6[a]
11	Phostex .62 (TO)	1.2	2.0	12-11-57	Suisun	Peach	17.0	100.0[a]
12	Phostex 8.0 (C)	1.2	2.0	12-30-57	Suisun	Apricot	24.4	100.0[a]
13	None	—	3.0	2-21-58	Almaden	Prune	32.3	98.5[b]

[a] European fruit lecanium.
[b] Frosted scale.

both ethion and oil. While the rates of 0.38 pounds ethion and 1.0 gallon oil considerably reduced the number of scales, the amount of reduction was not considered adequate for seasonal control. Another group of trials (6–10) illustrated the effectiveness of ethion when used in combination with 2 gallons of oil. All rates of ethion, from 0.28 to 0.47 pounds, provided excellent scale control. In a final test (trial 11), it was shown that equivalent results were obtained with less oil (1.5 gallons) where the ethion rate was increased to 0.56 pounds.

The data clearly indicate the interdependence of ethion and oil for scale control. The optimum rates of oil and ethion, within the limits of the dosages investigated, appear to be approximately 0.32 pounds ethion and 2 gallons oil. It is possible that equivalent scale control could also be obtained with less ethion at a 3-gallon oil level. However, since the higher amount of oil is less desirable from the standpoint of tree injury due to oil-soaking, this point was not investigated.

A similar series of trials designed to evaluate Phostex-oil sprays for San Jose scale control were also carried out. Data are presented in table 2 to illustrate the control obtained with Phostex and oil against this scale insect. Phostex at 1.2 pounds plus oil at 1.5 gallons (trials 12 and 13) gave considerable but insufficient control. The control was markedly improved when Phostex was used at 1.2 to 1.5 pounds and the oil increased to 2.0 gallons (trials 14–17). These rates of Phostex and oil appear to be optimum for use against this scale species.

Also included in this table are results obtained with 0.75 pounds malathion and 2 gallons oil (trial 18), 0.5 pounds parathion and 2 gallons oil (trial 19), and 5.0 gallons oil without a toxicant additive (trial 20). Straight oil at this rate gave excellent control as did the combination

Table 2.—Results of dormant sprays against San Jose scale on deciduous trees in California. 1956–58.

Trial No.	Phosphate Toxicant	Pounds Actual Toxicant/100 Gal. Water	Gal. Dormant Oil/100 Gal. Water	Date Applied	Location	Crop	Per Cent Dead Scale	
							Pre-treatment	Post-treatment
1	Ethion .38 (TO)	0.19	0.5	11-16-58	Empire	Peach	71.3	91.4
2	Ethion .38 (TO)	0.19	0.5	12-20-56	Yuba City	Peach	46.7	87.8
3	Ethion .38 (TO)	0.38	1.0	10-25-56	Gridley	Peach	81.0	96.3
4	Ethion .38 (TO)	0.38	1.0	11-16-56	Empire	Peach	74.5	96.5
5	Ethion .38 (TO)	0.38	1.0	12-20-56	Yuba City	Peach	43.8	94.8
6	Ethion .38 (TO)	0.28	2.0	1-31-57	Hamilton City	Almond	79.5	99.4
7	Ethion .16 (TO)	0.32	2.0	1-22-58	Princeton	Prune	—[a]	98.7
8	Ethion .16 (TO)	0.32	2.0	1-22-58	Hamilton City	Prune	—[a]	99.7
9	Ethion .38 (TO)	0.38	2.0	1-30-57	Yuba City	Peach	86.5	99.0
10	Ethion .38 (TO)	0.47	2.0	1-31-57	Hamilton City	Almond	37.8	99.7
11	Ethion .38 (TO)	0.56	1.5	1-30-57	Yuba City	Peach	84.2	99.7
12	Phostex .76 (TO)	1.2	1.5	12-20-56	Yuba City	Peach	39.7	96.3
13	Phostex .76 (TO)	1.2	1.5	2- 5-57	Loomis	Prune	—[a]	97.1
14	Phostex .76 (TO)	1.2	2.5	1-30-57	Yuba City	Peach	85.5	100.0
15	Phostex .62 (TO)	1.2	2.0	1-22-58	Hamilton City	Prune	—[a]	99.8
16	Phostex .76 (TO)	1.5	2.0	1-31-57	Hamilton City	Almond	80.9	99.6
17	Phostex .76 (TO)	1.5	2.0	1-30-57	Yuba City	Peach	86.2	99.8
18	Malathion .25 (WP)	0.75	2.0	12-20-56	Yuba City	Peach	36.2	95.2
19	Parathion .25 (WP)	0.50	2.0	11-16-56	Empire	Peach	76.5	99.5
20	None	—	5.0	1-30-57	Yuba City	Peach	84.5	99.6

[a] No precount taken because unsprayed trees were available for final evaluation.

Table 3.—Results of dormant sprays against olive scale on peach trees in California. 1956–58.

Trial No.	Phosphate Toxicant	Pounds Actual Toxicant/ 100 Gal. Water	Gal. Dormant Oil/100 Gal. Water	Date Applied	Location	Per Cent Dead Female Scale		
						Pre-treatment Twigs	Posttreatment Twigs	Posttreatment Bark
1	Ethion .16 (TO)	0.50	3.0	1-10-58	Madera	—[a]	100.0	99.4
2	Ethion .38 (TO)	.50	3.0	1-29-57	Clovis	44.5	99.7	100.0
3	Ethion .38 (TO)	.50	3.0	1-30-57	Tipton	40.2	99.6	97.7
4	Ethion .16 (TO)	.50	3.0	2-10-58	Hanford	—[a]	98.3	99.2
5	Ethion .38 (TO)	.75	2.0	1-25-57	Hanford	51.5	92.7	82.5
6	Ethion .38 (TO)	.75	3.0	1-30-57	Tipton	40.2	100.0	99.0
7	Ethion .38 (TO)	.50	3.5	1-25-57	Hanford	53.6	100.0	98.3
8	Phostex .76 (TO)	1.6	3.5	1-25-57	Hanford	50.5	100.0	96.0
9	Phostex .62 (TO)	2.4	3.5	1-25-57	Hanford	52.2	100.0	98.1
10	Phostex .62 (TO)	1.8	3.0	2-10-58	Hanford	—[a]	98.4	96.3
11	Phostex .62 (TO)	2.4	3.0	1-30-57	Tipton	45.6	99.4	98.1
12	Trithion 4.0 (C)	.50	3.0	1-29-57	Clovis	51.6	99.6	98.5
13	Trithion 4.0 (C)	.50	3.0	1-30-57	Tipton	37.4	98.4	95.0
14	Trithion 4.0 (C)	.50	3.5	1-25-57	Hanford	59.7	99.8	96.7
15	Trithion 4.0 (C)	.75	1.5	1-29-57	Clovis	55.0	90.4	82.6
16	Parathion .25 (WP)	.50	3.0	1-29-57	Clovis	51.8	98.5	98.6
17	None	—	4.0	2- 8-56	Dinuba	—[a]	70.0	26.0

[a] No precount taken because unsprayed trees were available for final evaluation.

of parathion and oil. The malathion-oil spray gave partial control but was not as effective as either the oil or the parathion-oil spray.

The data in table 3 summarizes results with ethion-oil and Phostex-oil sprays for the control of olive scale. In the first four trials where ethion was applied at 0.5 pounds in combination with oil at 3 gallons, the olive scale control was excellent. When the rate of oil was reduced to 2 gallons, the control was considerably less even though the amount of ethion was increased to 0.75 pounds (trial 5). When this high rate of ethion (0.75 pounds) was combined with the 3-gallon rate of oil, the control was again excellent (trial 6), but no better than that obtained with the 0.5 pounds to 3 gallons of ethion-oil. In another trial (7), the rate of ethion was held at 0.5 pounds and the oil was increased to 3.5 gallons. This also provided excellent olive scale control, but was no better than the 0.5 pound–3 gallon ethion-oil combination.

Table 3 also includes work carried out with Phostex and oil. The rate of Phostex was varied from 1.6 to 2.4 pounds (trials 8–11) and the rate of oil was varied from 3 to 3.5 gallons. All of the rates tested provided good control but the best results were obtained at approximately the 2.0 pounds to 3 gallons level of Phostex and oil.

For comparative purposes, four trials involving Trithion®(*S*-(*p*-chlorophenylthio) methyl *O,O*-diethyl phosphorodithioate) are included in this table. A combination of 0.5 pounds Trithion and 3 gallons oil gave good control (trials 12 and 13). Equivalent control was also obtained with 0.5 pounds Trithion and oil at 3.5 gallons (trial 14). When the oil was dropped to 1.5 gallons, the control was again much reduced even though the amount of Trithion was increased to 0.75 pounds (trial 15).

The regularly recommended spray of 0.5 pounds parathion plus 3 gallons oil was included to complete the comparison. As can be seen in the table, the control obtained with this spray (trial 16) was excellent. To determine the effectiveness of oil alone, a spray containing 4 gallons of oil was also applied (trial 17). This spray provided very little olive scale control.

In addition to controlling certain scale species, ethion-oil and Phostex-oil have been proven to be toxic to certain other pests present when applications are timed for scale control. Ethion-oil has given excellent control of the eggs of European red mite, *Panonychus ulmi* (Koch); clover mite, *Bryobia praetiosa* Koch; rosy apple aphid, *Anuraphis roseus* Baker; leaf curl plum aphid, *A. helichrysi* Kalt.; hop aphid, *Phorodon humuli* (Schr.); mealy plum aphid, *Hyalopterus pruni* (Geoffroy); and the black cherry aphid, *Myzus cerasi* (F.); during the dormant and delayed dormant periods. Phostex-oil has also exhibited excellent control of these aphid species and good control of the mites mentioned when applications are restricted to the delayed dormant period.

The compatibilities of ethion-oil and Phostex-oil mixtures with other insecticides and fungicides have not been fully explored. Preliminary investigations have shown both mixtures to be compatible with basic zinc sulphate, zinc carbamate, and fixed copper compounds. Ethion-oil has been successfully combined with lime-sulfur and polysulphide compound (contains 96% Na polysulphide). It has been demonstrated that Phostex-oil is not compatible with these two materials.

References Cited

Howard, L. O. 1898. The San Jose scale in 1896–97. U. S. Dept. Agric. Div. of Ent. Bull. **12**: 6.

Quaintance, A. L. 1915. The San Jose scale and its control. U. S. Dept. Agric. Farmers' Bull. 650: 26–27.

Quayle, H. J. 1943. The increase in resistance in insects to insecticides. Jour. Econ. Ent. **36**(4): 493–4.

Smith, J. P. 1897. San Jose scale and how it may be controlled. New Jersey Agric. Expt. Sta. Bull. **125**.

Weldon, G. P. 1918. Pear growing in California. California State Comm. Hort. Bull. **7**(5): 403.

Two New Phosphates for Control of Overwintering Eggs of Aphids and Mites on Deciduous Fruit Trees[1]

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Abstract

Ethion in combination with dormant oil has given excellent control of several mite and insect species when applied as a dormant or delayed dormant spray. Phostex-oil sprays have given excellent control of aphid species when applications are restricted to the delayed dormant period. Phostex® is a mixture of bis(dialkyloxyphosphinothioyl)disulphides. The mite control during the delayed dormant period with Phostex-oil has in general been fairly good. The species controlled include the rosy apple aphid, *Anuraphis roseus* Baker; mealy plum aphid, *Hyalopterus pruni* (Geoffroy); black cherry aphid, *Myzus cerasi* (F.); European red mite, *Panonychus ulmi* (Koch); and the clover mite, *Bryobia praetiosa* Koch.

Trials were conducted in California over a 3-year period. Tests were applied from January through March in an attempt to determine timing of application in relation to control. In general, more toxicant and oil were needed during the dormant than during the delayed dormant period for equivalent control of rosy apple aphid, European red mite, and clover mite. The amount of toxicant and oil required for control of mealy plum aphid and black cherry aphid was constant all during the dormant period.

Dormant and delayed dormant sprays of ethion-oil and Phostex-oil have given excellent control of rosy apple aphid, *Anuraphis roseus* Baker; mealy plum aphid, *Hyalopterus pruni* (Geoffroy); black cherry aphid, *Myzus cerasi* (F.); European red mite, *Panonychus ulmi* (Koch); and the clover mite, *Bryobia praetiosa* Koch. Phostex® is a mixture of bis(dialkyloxyphosphinothioyl)disulphides.

Madsen & Bailey (1958a) mentioned ethion-oil and Phostex-oil sprays as effective controls of the leaf curl plum aphid, *A. helichrysi* Kalt. Madsen & Bailey (1958b) also made reference to ethion-oil sprays as a control for rosy apple aphid and European red mite. In their work, Phostex-oil gave excellent aphid control but limited mite control.

Early workers, Quaintance & Baker (1917) and Davidson (1919) suggested the use of contact insecticides for controlling the aphid stem mothers during the early spring period. This was a critical spray in that it had to be applied shortly after the stem mothers had hatched, and before they had begun to curl the leaves. Later experimenters, Parrott & Glassgow (1930), Hartzell & Parrott (1933) and Smith (1937), used coal-tar distillates as dormant sprays against the eggs of various aphid species. This spray was less critical as to timing but only partially effective.

Hough (1939) used dinitro compounds, alone and in combination with oil, for the control of overwintering apple aphid eggs. The use of dinitro-oil sprays for aphid control during the dormant and delayed dormant periods has become one of the most widely accepted control measures in the western fruit growing region. When properly applied, this treatment has proven to be very effective for the control of aphid eggs.

The use of dinitro-oil sprays is objectionable for several reasons. Because of their caustic nature, the dinitro materials are not only annoying to the applicator but severely burn any cover crop present at the time of the application. The aphid control obtained with such chemicals is excellent when applications are restricted to the delayed dormant period, but is incomplete with earlier applications. Mite control has not been satisfactory in many instances.

Phosphate-oil combinations containing ethion or Phostex offer many advantages over dinitro-oil sprays. Neither ethion-oil nor Phostex-oil is injurious to the cover crop. In addition, both materials are safe to handle using normal equipment and precautions. Ethion-oil has given excellent control of aphid and mite eggs when applied during the dormant as well as delayed dormant periods. Phostex-oil sprays have provided excellent aphid control and good mite control (equal to dinitro-oil) when applied in the delayed dormant period. Combinations of Phostex-oil and ethion-oil have been tested in California for a period of 3 years.

Procedure.—The early trials (1956) consisted of small (two to three tree) apple plots. The sprays were applied during the delayed dormant period with hand-gun type equipment. Results of treatments against aphids were made by visually observing the numbers of infested fruit and leaf clusters per tree.

In 1957, five trials were conducted on apples and prunes. Plot size was approximately 1 acre and the plots were not replicated. Applications of materials were again made only during the delayed dormant period. Tests were conducted under actual field conditions using application equipment available at each location. Results of aphid control were obtained by the visual system and counts were taken from 10 to 20 trees within each plot. Mite counts were made by taking random samples of 25 to 50 leaves per plot and recording the numbers of adult mites present.

In 1958, a total of 13 trials were conducted on apples, prunes and cherries. Plot size was again approximately 1 acre and plots were not replicated. Tests were arranged to compare effectiveness of dormant and delayed dormant applications. Applications of materials were begun in January and continued into March to investigate optimum time of application and ratio of toxicant to oil in relation to control. Materials were applied by blower-type or hand-gun equipment, and gallons per acre depended upon local practices. Observations on control of mites and aphids in most tests were made by the systems already presented. In some trials the numbers of infested

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Table 1.—Results of treatments against rosy apple aphid and European red mite on apples with dormant and delayed dormant applications. Watsonville, California. 1958.

Material	Lb. Actual Toxicant/100	Gal. Actual Oil/100	Date Applied	No. of Aphid Clusters per 10 Trees on			Total Mites per 25 Leaves on May 1
				Apr. 18	May 1	May 21	
Phostex 0.62 (TO)	0.62	0.9	Jan. 21	3	26	100+	136
Ethion 0.16 (TO)	.16	1.0	Jan. 21	0	2	3	32
Ethion 0.16 (TO)	.32	2.0	Jan. 21	0	0	0	7
Phostex 0.62 (TO)	.62	0.9	Feb. 27	0	0	0	7
Ethion 0.16 (TO)	.16	1.0	Feb. 27	0	0	0	8
Ethion 0.16 (TO)	.32	2.0	Feb. 27	0	0	0	3
Dinitro 0.40 (WP[a]) plus Dormant flowable oil	.40	3.2	Feb. 28	0	0	0	10
Untreated	—	—	—	—	36[b]	100+[b]	523

[a] Contains 40% DNOC.
[b] Per four trees.

trees per plot were also determined for aphid control. Evaluation of trials was usually made twice after treatments had been applied.

Chemicals employed in all trials have been designated in the tables as concentrates (C), toxicants dissolved in dormant oil (viscosity—SSU 120 at 100°F., UR—80) (TO), and wettable powders (WP). The numbers associated with the (C) and (TO) designations refer to the pounds of active ingredient per gallon, while the (WP) refers to the pounds of active ingredient per pound of formulated material.

Results and Discussion.—The results obtained in 1956 with delayed dormant sprays were very promising. Excellent aphid control was obtained with ethion-oil, Phostex-oil, and the standard dinitro-oil.

The 1957 trials also gave excellent aphid control. In addition, ethion-oil gave excellent control of European red mite and clover mite. This mite control was much better than that provided by Phostex-oil or dinitro-oil.

The results of the 1958 trials were also excellent. There were no failures in aphid control with any applications of ethion-oil to prune and cherry. Applications to apple, however, showed that an increased amount of toxicant and oil was necessary to obtain aphid control during the dormant period (January) over that required during the delayed dormant period (March). The mite control was generally excellent, but varied depending upon the time of application and the amount of material applied.

Excellent control of aphids with Phostex-oil and dinitro-oil sprays was also obtained when the applications were restricted to the delayed dormant period. Mite control with these materials as delayed dormant sprays was good, but was not as good as that provided with ethion-oil. Phostex-oil did not provide adequate aphid or mite control as dormant (January) sprays.

The data presented in the tables are typical of the experimental results obtained over the 3-year period.

The data in table 1 represents control of rosy apple aphid and European red mite on apples. The comparison in this trial was that of dormant applications (January 21, 1958) of two rates of ethion-oil, and one rate of Phostex-oil as against delayed dormant (February 27, 1958) applications of the same materials at the same rates. The standard treatment of dinitro and oil as a delayed dormant spray was included for comparison. All materials were applied by hand-gun and full coverage was obtained.

The dormant spray of ethion-oil at the high rate provided excellent control of both aphids and mites. The lower rate provided good mite and aphid control but was not as effective as the higher rate. The Phostex-oil spray applied in the dormant gave little or no control of the aphid or mite species involved. All materials at all rates used in this trial gave excellent control of aphids and mites when the applications were made in the delayed dormant period. No differences in control between materials or rates could be determined at this application time.

Table 2 summarizes the results of work done in a prune orchard. The insects and mite species evaluated in this test were the mealy plum aphid and a mixed population of European red and clover mites. In this trial, the comparsion of dormant (January 9, 1958) and delayed dormant (February 27, 1958) applications of ethion-oil and Phostex-oil was made. An untreated area was available for comparison. All sprays were applied by blower-type spray equipment at 500 gallons per acre and excellent coverage was obtained. Rates of respective materials were kept constant for each spray date so that direct comparison between time of application and control obtained could be made.

The aphid control with ethion-oil as either a dormant or delayed dormant spray was complete. The mite control with this same material was also excellent. The later application provided slightly better control than the earlier spray. The early application of Phostex-oil gave little aphid control and practically no mite control. The delayed dormant spray of Phostex-oil, however, gave excellent control of both mites and aphids, being only

Table 2.—Results of treatments against mealy plum aphid, European red mite and clover mite on prune with dormant and delayed dormant applications. Mt. View, California. 1958.

Material Plus Dormant Flowable Oil	Lb. Actual Toxicant/100	Gal. Actual Oil/100	Date Applied	Per Cent Trees Infested with Aphids/10 Examined on		Total Mites per 25 Leaves on	
				May 6	May 20	May 6	May 20
Ethion 5.0 (C)	0 16	0.8	Jan. 9	0	0	9	6
Phostex 8.0 (C)	.62	0.8	Jan. 9	0	20	31	51
Ethion 5.0 (C)	.16	0.8	Feb. 27	0	0	0	2
Phostex 8.0 (C)	.62	0.8	Feb. 27	0	0	6	9
Untreated	—	—	—	30	40	32	151

Table 3.—Results of treatments against mealy plum aphid and clover mite on prune with a delayed dormant application. Hollister, California. 1958.

Material[a] Plus Dormant Flowable Oil	Lb. Actual Toxicant/100	Gal. Actual Oil/100	Per Cent Trees Infested with Aphids/10 Examined on May 9	Per Cent Trees Infested with Aphids/10 Examined on May 27	Total Mites per 25 Leaves on May 9	Total Mites per 25 Leaves on May 27
Ethion 5.0 (C)	0.16	1.3	0	0	0	4
Phostex 8.0 (C)	.62	1.3	0	0	65	135
Dinitro .40 (WP[b])	.40	3.4	0	0	5	49
Untreated	—	—	30	—[c]	310	—[c]

[a] All materials applied February 28, 1958.
[b] Contains 40% DNOC.
[c] Sprayed with parathion.

Table 4.—Results of treatments against black cherry aphid, European red mite and the clover mite on cherries with dormant and delayed dormant applications. Mt. View, California. 1958.

Material Plus Dormant Flowable Oil	Lb. Actual Toxicant/100	Gal. Actual Oil/100	Date Applied	Per Cent Trees Infested with Aphids/10 Examined on May 6	Per Cent Trees Infested with Aphids/10 Examined on May 20	Total Mites per 25 Leaves on May 6	Total Mites per 25 Leaves on May 20
Ethion 5.0 (C)	0.16	0.8	Jan. 9	0	0	2	14
Phostex 8.0 (C)	.62	0.8	Jan. 9	0	0	70	58
Ethion 5.0 (C)	.16	0.8	Feb. 27	0	0	3	0
Phostex 8.0 (C)	.62	0.8	Feb. 27	0	0	47	59
Untreated	—	—	—	30	40	73	97

slightly inferior in mite control to the ethion-oil spray applied at the same time.

Table 3 illustrates the control of mealy plum aphid and clover mite on prune. In this trial all materials were applied during the delayed dormant period (February 28, 1958). The comparison of the control obtained with ethion-oil, Phostex-oil, and dinitro-oil was made against an untreated area. Application of materials was by blower-type equipment with good coverage at 400 gallons of finished spray per acre.

The aphid control was excellent with all materials involved. The mite control, however, depended upon the material used. At the time of the first evaluation, the ethion-oil and dinitro-oil sprays were equivalent. However, when the second counts were made, the ethion-oil spray was far superior to both the dinitro-oil and Phostex-oil sprays. The dinitro-oil mixture gave better control than the Phostex-oil at both evaluation dates. The Phostex-oil in turn was superior to the untreated portion. The number of mites per leaf indicated in the second evaluation showed the need of additional control measures for both dinitro-oil and Phostex-oil. This additional spray was not needed for the ethion-oil plot.

The data in table 4 represents control of the black cherry aphid and a mixed population of European red and clover mites on cherry. The comparison in this test consisted of dormant (January 9, 1958) and delayed dormant (February 27, 1958) applications of ethion-oil and Phostex-oil. An untreated area was available for observation. Materials were applied by blower-type equipment at 500 gallons per acre. Each material was used at the same rate for each application. This allowed for a direct comparison between time of application in relation to control.

The aphid control with both materials at both application dates was excellent. The ethion-oil provided considerably more mite control than Phostex-oil at both application times.

Preliminary investigations have shown ethion-oil and Phostex-oil combinations to be very effective in controlling the apple aphid, *Aphis pomi* DeG. However, owing to early reinfestation from alternate plant host species, data are not presented. In a single trial, ethion-oil and Phostex-oil gave excellent control of the hop aphid, *Phorodon humuli* (Schr.)

Ethion-oil and Phostex-oil have also provided excellent control of many species of scale during the dormant period. These included the San Jose scale (*Aspidiotus perniciosus* Comst.), olive scale (*Parlatoria oleae* (Colvée)), European fruit lecanium (*Lecanium corni* Bouché), soft scale (*Coccus hesperidum* L.), and the frosted scale (*L. pruinosum* Coq.).

References Cited

Davidson, W. M. 1919. Life history and habits of the mealy plum aphis. U. S. Dept. Agric. Bull. **774**: 15.

Hartzell, F. Z., and P. J. Parrott. 1933. Tar distillate emulsions for the control of the rosy aphid and other fruit insects. New York State Agric. Expt. Sta. Bull. **636**: 18–20.

Hough, W. S. 1939. Dinitro-O-cresol, dinitro-O-cyclo-hexylphenol and laurel rhodanate in dormant sprays against eggs of apple aphids. Jour. Econ. Ent. **32**(2): 264–70.

Madsen, H. F., and J. Blair Bailey. 1958a. Biology and control of the leaf curl plum aphid in Northern California. Jour. Econ. Ent. **51**(2): 226–9.

Madsen, H. F., and J. Blair Bailey. 1958b Rosy apple aphid control tests. California Agric. **12**(1): 3.

Parrot, P. J., and Hugh Glasgow. 1930. The rosy aphid in relation to spray practices in 1929. New York State Agric. Expt. Sta. Bull. **582.**

Quaintance, A. L., and A. C. Baker. 1917. Aphids injurious to orchard fruits, currant, gooseberry, and grape. U. S. Dept. Agric. Farmers' Bull. **804**: 34–41.

Smith, L. M. 1937. Control of the mealy plum aphid. Univ. California Agric. Expt. Sta. Bull. **606.**

Fall Dusting to Control the Sheep Ked[1]

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ABSTRACT

Greater difficulty has been experienced in eradicating infestations of sheep ked, *Melophagus ovinus* (L.), by power dusting in fall than in spring after shearing. Tests have shown that although a 1.5% dieldrin dust will eradicate an infestation of keds in spring, a 5% dieldrin dust is needed in fall for equal effectiveness. Diazinon® (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate) at 5% also provided eradication in fall, but the following dusts did not: 3% dieldrin, 1.5% aldrin, 5% Co-ral® (*O*-(3-chloro-4-methylumbelliferone) *O,O*-diethyl phosphorothioate), 1% Diazinon, 5% dicapthon, 5% Korlan® (*O,O*-dimethyl *O*(2,4,5-trichlorophenyl) phosphorothioate), and 5% malathion.

Hand-dusting tests likewise showed that keds were harder to eradicate in fall than in spring. Of the insecticidal dusts tested both in spring and fall, 1.5% dieldrin, 5% malathion, and 5% Korlan eradicated infestations of sheep ked every time tested.

Power dusting of sheep with 1.5% dieldrin has become a widespread practice among wool growers in the Rocky Mountain states to control infestations of sheep ked, *Melophagus ovinus* (L.). When growers properly treat sheep after shearing in spring, infestations of the parasite are eradicated. Tests have shown, however, that fall dusting is not equally effective, since treatments at this time have reduced ked populations from only 5% to 88% (Pfadt & DeFoliart 1957).

There may be several reasons why eradication is more difficult to achieve in fall than in spring. First, the wool is longer and may prevent the dust from reaching the parasites; second, the greater amount of wool, grease, and dirt may substantially dilute the insecticide; third, populations of keds are usually increasing in fall but decreasing in late spring and summer; fourth, cool fall temperatures keep the keds close to the skin and perhaps away from the insecticide, whereas higher temperatures of late spring and summer stimulate migration.

These conceivable causes for greater difficulty of control evoked the question whether one could eradicate infestations of sheep ked in fall by applying somewhat higher concentrations of dieldrin dust than 1.5%. To answer this we conducted tests with dusts containing 3% and 5% dieldrin.

Because other insecticides, particularly the new and less toxic phosphates, might possess the qualities needed for effective fall control, we likewise tried 1.5% aldrin, 5% Co-ral® (*O*-(3-chloro-4-methylumbelliferone) *O,O*-diethyl phosphorothioate), 1% and 5% Diazinon® (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate), 5% dicapthon, 5% Korlan® (*O,O*-dimethyl *O*(2,4,5-trichlorophenyl) phosphorothioate), and 5% malathion.

In this paper results are also reported on hand-dusting sheep in spring after shearing and in fall. Although the primary purpose of these tests was to find suitable dusts and methods that owners of small numbers of sheep could use inexpensively and effectively to control sheep keds, the tests provided some insight into the reasons why it is more difficult to control keds in fall than in spring.

METHODS.—In the power-dusting trials entire flocks were treated in October with a single material and were considered a single test. The flocks ranged in size from 74 to 730 animals and averaged 266.

Assessment of degree of infestation was made by counting the keds on 5 lambs and 5 ewes selected from each flock. Each animal examined was gone over entirely. As pointed out by Nelson *et al.* (1957), the "total live count" method provides a high degree of accuracy in that a relatively large portion of the actual population is counted. A pretreatment count was made just before dusting each flock. The posttreatment count was made 4 weeks after dusting in 1957, but as this interval was not always long enough to allow all pupae to complete development and emerge as adults, the posttreatment count in 1958 was extended to 7 weeks after dusting.

For comparison with the tests, untreated flocks in the same area (Platte County, Wyoming), were examined for keds in the same way and at the same intervals as treated flocks. Percentage reduction of keds, however, was calculated from the pre- and posttreatment counts of each individual treated flock without the use of a formula such as Abbott's.

Sheep were dusted by driving the animals through a curtain of dust generated by a power duster and expelled from a steel sheep chute (Howry-Berg Sheep Duster).

In the hand-dusting trials entire flocks were also treated with a single material and were considered a single test. The flocks, however, were smaller than in the power-dusting tests, ranging from 10 to 75 and averaging 40 sheep per flock.

The method of treatment consisted of catching each sheep in a flock, placing it on its side, sifting the dust onto the wool from the neck down the side to the breech and on the belly, then rubbing the wool lightly with the hand to work the dust down to the skin. The opposite side of the sheep was treated similarly. The device used in dispensing the dusts was a Foley 1-cup sifter. It worked better and faster than a shaker jar, which often clogged up. In spring the amount of dust applied per head was 2 oz. per adult sheep and 1 oz. per lamb; in fall, when lambs were large, 2 oz. per head were applied to all ages of sheep. Two men dusting sheep confined in a corral were able to treat a flock at an approximate rate of one sheep per minute.

The same method of assessing results was used on the hand-dusted flocks as on the power-dusted flocks.

RESULTS AND DISCUSSION.—Power-dusting tests in fall revealed two materials, 5% dieldrin and 5% Diazinon, sufficiently potent to provide eradication of infestations of the sheep ked (table 1). The 5% concentration of

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dieldrin dust appeared to be near the minimum that will provide eradication in fall, since a 3% dieldrin dust did not eradicate infestations. On the other hand it may be possible to lower the concentration of Diazinon from the 5% found effective to a lower amount, since a 1% dust gave an 88% reduction of keds and no concentration between 1% and 5% was tried.

The next most effective dust appeared to be 5% Korlan which in three tests gave ked reductions of 94%, 97%, and 98%. Less effective were 5% Co-ral, 5% dicapthon, 5% malathion, and 1.5% aldrin.

Until residue tests are run, neither 5% dieldrin nor 5% Diazinon can be recommended at this time for fall application to sheep. Furthermore, additional testing of these concentrations is necessary to confirm the 1958 results. An unexplained result was the complete effectiveness of 5% dieldrin dust applied at the rate of 2.1 lb. per minute but not of 3% at 3.6 lb. per minute. The latter result was confirmed by a posttreatment examination at 4 months as well as at 4 weeks.

Hand-dusting tests disclosed a large number of insecticides that consistently eradicated infestations of sheep ked on shorn sheep in spring (table 2). This group included 10% DDT, 1.5% dieldrin, 1.5% heptachlor, 50% methoxychlor, 5% toxaphene, 1% Diazinon, 5% Korlan, 5% malathion, and 1.5% rotenone. Less effective dusts included 5% DDT, 1% lindane, and 10% methoxychlor. Since 10% DDT and 1.5% rotenone were tested only once, the reliability of the results may be questioned. Yet the results of Dicke *et al.* (1949) who, using a rotary duster in spring on unshorn sheep, found 1% rotenone dust more effective in controlling sheep keds than BHC dust (1% gamma), seem to confirm ours.

Although not all materials tested in spring were tried in fall, results indicated that hand dusting was not as effective in fall as in spring (table 3). The insecticides which provided eradication at both times included 1.5% dieldrin, 5% malathion, and 5% Korlan. Schwardt & Matthysse (1948) found hand application of a rotenone-wettable sulfur dust completely effective against keds in fall. Though table 3 shows 1.5% dieldrin giving a 99% reduction at the end of 4 weeks, an examination of the flock 4 months after treatment revealed no keds. The lone ked found the fourth week after treatment had emerged on the day of the examination.

Insecticides that gave consistent eradication in spring but not always in fall included 50% methoxychlor, 5% toxaphene, and 1.5% rotenone. Since in the hand-dusting

Table 1.—Results of power-dusting 23 flocks of sheep in fall to control sheep keds.

Dust	Dusting Rate (Lb./Min.)	Mean Number of Keds per Sheep		Percentage Reduction
		Before Treating	After Treating	
Aldrin 1.5%	2.2	17.0	7.3[a]	57
	3.3	7.1	3.3[a]	54
Dieldrin 3%	3.6	6.4	0.1[a]	98
	2.6	36.4	2.0[a]	95
Dieldrin 5%	2.1	9.0	0[b]	100
	3.0	10.9	0[b]	100
Co-ral 5%	2.6	4.0	0.8[b]	80
	2.1	14.5	0.9[b]	94
Diazinon 1%	3.3	16.5	2.0[a]	88
Diazinon 5%	1.6	2.8	0[b]	100
	3.6	17.6	0[b]	100
Dicapthon 5%	2.0	16.4	4.6[b]	72
	2.0	7.3	3.7[b]	49
Korlan 5%	3.0	62.7	3.7[a]	94
	2.6	20.3	0.7[b]	97
	2.9	29.3	0.5[b]	98
Malathion 5%	1.0	40.7	17.1[a]	58
	4.3	19.0	3.9[a]	79
	1.9	8.5	0.4[b]	95
	1.9	20.5	8.9[b]	57
Untreated		61.2	48.7[a]	20
		17.4	22.3[b]	− 28
		22.0	44.1[b]	−100

[a] Examination made 4 weeks after treatment in 1957.
[b] Examination made 7 weeks after treatment in 1958.

Table 2.—Results of hand-dusting 26 flocks of shorn sheep in spring at rate of 1 ounce dust per lamb and 2 ounces dust per ewe for control of sheep keds.

Dust	Mean Number of Keds per Sheep		Percentage Reduction
	Before Treating	6 Weeks After Treating	
DDT 5%	7.5	0.6	92
	36.3	3.4	91
DDT 10%	27.7	0	100
Dieldrin 1.5%	50.1	0	100
	28.1	0	100
Heptachlor 1.5%	42.9	0	100
	168.9	0	100
Lindane 1%	31.8	0	100
	94.1	0.2	99.8
Methoxychlor 10%	5.6	0	100
	21.5	0	100
	6.0	0.1	98
Methoxychlor 50%	22.3	0	100
	16.2	0	100
	5.7	0	100
Toxaphene 5%	3.9	0	100
	18.2	0	100
Diazinon 1%	74.9	0	100
	12.6	0	100
Korlan 5%	1.8	0	100
Malathion 5%	76.4	0	100
	39.1	0	100
Rotenone 1.5%	23.0	0	100
Untreated	45.3	35.2	22
	14.2	15.9	− 12
	62.6	16.5	74

Table 3.—Results of hand-dusting 14 flocks of sheep in fall at rate of 2 ounces dust per head for control of sheep keds.

Dust	Mean Number of Keds per Sheep		Percentage Reduction
	Before Treating	After Treating	
Dieldrin 1.5%	15.5	0.1[a]	99
Methoxychlor 50%	42.2	0.4[a]	99
	24.2	0.1[b]	99.6
	6.8	0[b]	100
Toxaphene 5%	112.7	3.5[b]	97
Co-ral 5%	14.3	0.2[a]	99
Korlan 5%	8.8	0[a]	100
Malathion 5%	3.2	0[a]	100
	15.0	0[b]	100
Rotenone 1.5%	12.8	0.1[b]	99
	11.5	0[b]	100
Untreated	61.2	48.7[a]	20
	17.4	22.3[b]	− 28
	22.0	44.1[b]	−100

[a] Examination made 4 weeks after treatment in 1957.
[b] Examination made 7 weeks after treatment in 1958.

method the insecticide is worked into the wool, penetration could not be a factor in reduced efficiency in fall. It seems likely that dilution of the insecticide by the larger amount of wool and of dirt and grease in the wool is an important cause of greater difficulty in achieving eradication in fall.

In the spring of 1957 one flock of 100 lambs and 230 shorn adult sheep were treated with 1.5% dieldrin dust dispensed from a hand-operated rotary garden duster. The ked population was eradicated, as a pretreatment examination showed an infestation of 9.3 keds per head while a posttreatment examination 6 weeks later revealed no keds. More extensive tests on the use of this type of duster to apply 1.5% dieldrin for the control of sheep keds was made by Goulding (1958) in Oregon.

References Cited

Dicke, R. J., A. L. Pope, and R. W. Bray, 1949. Investigation of rotenone and benzene hexachloride dusts for the control of insect ectoparasites on sheep. Jour. Agric. Res. **78:** 565–9.

Goulding, R. L. 1958. Sheep ked control in Oregon farm flocks. Jour. Econ. Ent. **51:** 585–7.

Nelson, W. A., S. B. Slen, and E. C. Banky, 1957. Evaluation of methods of estimating populations of the sheep ked, *Melophagus ovinus* (L.) (Diptera: Hippoboscidae), on mature ewes and young lambs. Canadian Jour. Animal Sci. **37:** 8–13.

Pfadt, R. E., and G. R. DeFoliart, 1957. Power dusting to control the sheep ked. Jour. Econ. Ent. **50:** 190–4.

Schwardt, H. H., and J. G. Matthysse. 1948. The sheep tick (*Melophagus ovinus* L.): materials and equipment for its control. Cornell Univ. Agric. Expt. Sta. Bull. **844.**

The Attraction of Stains to Three Species of Fabric Pests[1]

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Abstract

Large and small webbing clothes moth larvae, *Tineola bisselliella* (Hum.), are attracted to wool stained with human urine, human sweat, tomato juice, milk, beer, black coffee, and beef gravy. Small larvae of the furniture carpet beetle, *Anthrenus flavipes* Lec., also feed on such stains. Small larvae of the black carpet beetle, *Attagenus piceus* (Oliv.), are less attracted. Large larvae of the black carpet beetle show no preference for the stained areas. The large larvae of the furniture carpet beetle are attracted to beer and tomato juice stains, and show an occasional preference for the other stains. Wool stained with butter, tea, cola soft drink, and a 5% sugar solution does not attract any of the larvae.

Tests under starvation conditions showed that the larvae of the furniture carpet beetle fed on stained nylon and Dacron. The larvae of the black carpet beetle fed on nylon stained with human sweat. Stained Orlon and Dynel were not fed upon by any of the larvae of the three species.

The statement is often made that cleaning woolens by dry cleaning, or other methods, to remove dirt and stains protects them from feeding by clothes moths and carpet beetles. This study was undertaken to determine whether fabric pests are actually attracted to stains, and if they are, whether small and large larvae of clothes moths and carpet beetles are equally attracted to such stains. An additional study was made to determine if clothes moths and carpet beetles feed on stained synthetic textiles.

Colman (1932) showed that Vitamin B, as supplied in dry brewer's yeast, was essential to full development of clothes moth larvae, and Billings (1936) also showed that it is difficult to raise clothes moth larvae on thoroughly clean woolen goods. Anonymous (1952) recommends the use of powdered dry brewer's yeast to rear the black carpet beetle and the furniture carpet beetle. Fraenkel & Blewett (1945) replaced yeast in the diet of the clothes moth with a mixture of eight pure vitamins of the Vitamin B complex. They found growth retarded in the absence of either riboflavin, choline chloride, pyridoxin, or thiamin, and little or no growth taking place in the absence of pantothenic acid or nicotinic acid.

Materials and Methods.—AATCC Standard Test Cloth[2] is the white wool cloth used in the tests. This cloth

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[2] This cloth is specified in the CSMA (Chemical Specialties Manufacturers Association) Textile Resistance Test for Fabric Insects and is an undyed, scoured wool flannel which can be purchased from Test Fabrics, Inc. 55 Vandam Street, New York 13, N. Y.

was cut by means of a die (diameter 1.6″) into circles 2 square inches in area. The larvae used in the tests were reared according to specifications of the Chemical Specialties Manufacturers Association (CSMA) Textile Resistance Test, Anonymous (1952) and Heal (1942).

The insects used in the test were the larvae of the webbing clothes moth, *Tineola bisselliella* (Hum.), the black carpet beetle, *Attagenus piceus* (Oliv.), and the furniture carpet beetle, *Anthrenus flavipes* Lec.

The young larvae of the clothes moth were obtained by placing 20 eggs on the test cloth. Because the eggs of carpet beetles are fragile, these were not used. Instead, 20 newly emerged carpet beetle larvae of the first or second instar were placed with a camel's-hair brush on each piece of test cloth. In the tests where large larvae were used, 10 were placed on each piece of test cloth. The larger clothes moth larvae were from 24 to 27 days old from the date of egg deposition. The larger larvae of the black carpet beetle passed through a U. S. Standard Sieve Series No. 14 and were retained on a No. 16 sieve. Large larvae of the furniture carpet beetle measured from 2 to 3 mm. in length. The circles of test cloth in this test, as in a previous test, were handled at all times with forceps to keep them from being stained with perspiration.

A small mark was made with a pencil point, about 7 mm. from the edge, on a circle of test cloth. Then, a single drop of the staining material was applied by means of a small glass capillary tube, 3 mm. OD and 1.6 mm. ID. The stain on the cloth was permitted to dry for 24 hours and then the test cloth was placed in a 3-ounce seamless tin box, $2\frac{3}{4}$″ diameter by 1″ high. The box had a 60×60 mesh screen, 2″ in diameter, soldered into the lid. In this series of tests, four replicates were run with each stain. This was repeated at least once, for a minimum of eight replicates per stain. The test samples were held throughout the exposure period in a room with a temperature of 82° F ± 2° F. and an average relative humidity of 40%.

The attraction of the larvae to the stain was based on whether or not they ate a hole through the stained area. Where they were not attracted to the stain, they ate holes in the cloth other than through the stained area.

The common stains used in this test were human urine, human sweat, tomato juice, beer, beef gravy, butter, milk, black coffee, tea, cola soft drink, and a 5% sugar solution. It is, of course, understood that the above materials are not standardized and they vary in chemical composition according to the sample. Nevertheless, the same stain, from the same source, was used in all these tests.

The time necessary to determine whether or not the stain was attractive varied with the species and the size of the fabric pest. In the case of the smaller larvae, observations were required for 18 to 60 days. With the larger larvae 3 to 14 days were required.

The feeding on the stains was determined by visual examination and was rated as follows:

E—Definitely attracted to stain, made hole through stain before making hole elsewhere.
S—At times would feed on stain first, at other times elsewhere.
O—Showed no attraction to the stain; fed elsewhere in preference to stain.

RESULTS.—Table 1 shows the attraction of stains to larvae of the webbing clothes moth, the black carpet beetle, and the furniture carpet beetle.

Table 1.—Attraction of stains to larvae of the webbing clothes moth, the black carpet beetle, and the furniture carpet beetle.

Stain	Small Larvae			Large Larvae		
	Clothes Moth	Black Carpet Beetle	Furniture Carpet Beetle	Clothes Moth	Black Carpet Beetle	Furniture Carpet Beetle
Urine (human)	E	E	E	E	O	S
Sweat (human)	E	S	E	E	O	S
Tomato juice	E	E	E	E	O	E
Milk	E	S	E	E	O	S
Butter	O	O	O	O	O	O
Beer	E	E	E	E	O	E
Coffee (black)	E	S	E	O	O	O
Tea	O	O	O	O	O	O
Cola (soft drink)	O	O	O	O	O	O
Sugar solution (5%)	O	O	O	O	O	O
Gravy (beef)	E	S	S	E	O	S

It can be seen that attraction to some of the common stains varies with the species and to some extent with the size of the larvae. Urine, sweat, tomato juice, beer, milk, coffee, and gravy were attractive to the young larvae of all three species, although less so to the young larvae of the black carpet beetle. Tea, cola soft drink, 5% sugar solution, and butter were not attractive to the young larvae of any of the three species.

The large larvae of the webbing clothes moth were attracted to urine, sweat, tomato juice, milk, beer, and gravy stains. The large larvae of the black carpet beetle were not attracted to any of the above stains, and the large larvae of the furniture carpet beetle were definitely attracted to stains of tomato juice and beer, and avoided or showed only an occasional preference for the other stains. Agreement of results among replicates was quite uniform for the "E" and "O" classifications of attractiveness. As expected, results were more variable for the "S" classification.

Another series of tests was run with the large larvae of the three species of fabric pests, using 1 drop of tomato juice on a piece of test cloth and 10 drops of tomato juice on another piece to form a larger stain. Four replicates were run with each size of stain. It was observed that the large stain was no more attractive to the large larvae of the black carpet beetle than the small stain. Large larvae of the clothes moth and furniture carpet beetle were attracted to both small and large stains. During this test, observations were made on the time of emergence of the adults of the webbing clothes moth and the furniture carpet beetle. Observations on the emergence of the black carpet beetle, because of its much longer life cycle, were not completed in time for this report. Four pieces of test cloth were used for each species, with 10 larvae on each piece of cloth, for a total of 40 larvae of each species.

Table 2 shows the per cent emergence of adults of the webbing clothes moth and the furniture carpet beetle when large larvae were fed on small and large stains of tomato juice. It can be seen that tomato juice definitely accelerated the growth of these fabric insects. Observations were discontinued after 120 days.

Tests similar to those reported in table 1 were undertaken to determine if the three species of fabric pests fed on synthetic fabrics stained with three common stains readily eaten on wool.

Table 2.—Emergence of adults of the webbing clothes moth and furniture carpet beetle when large larvae were fed on small and large stains of tomato juice.

Stain	Per Cent Emergence of Moths in Days Shown				Per Cent Emergence of Furniture Carpet Beetles in Days Shown			
	70–80	81–100	101–120	Total 120	50–60	61–80	81–120	Total 120
Small tomato stain	5	20	5	30	33	13	28	74
Large tomato stain	60	5	13	78	60	13	18	91
No stain	0	5	3	8	0	3	3	6

The stains used in the test were three that seemed to be attractive to fabric pests, namely, tomato juice, human urine, and human sweat. These were placed on circular pieces of synthetic fabric 2 square inches in area so that each stain was equidistant from the other stain, and about 7 mm. from the edge of the cloth. The stains marked the angles of an equilateral triangle, and were deposited with the previously described capillary tube. The larvae used in the test were large larvae as described in the previous test. They were exposed to the stained synthetic fabric for 28 days.

Mallis *et al.* (1958) showed that synthetic textiles such as Orlon, Dynel, and Dacron were not fed upon after 2 weeks' exposure to larvae of the webbing clothes moth, the black carpet beetle, and the furniture carpet beetle. Nylon showed slight damage from feeding by black and furniture carpet beetles. It can be seen from the results in table 3 that the furniture carpet beetle extensively damaged nylon with all three stains, and the black carpet beetle damaged nylon stained with sweat. Dacron, which showed no damage in previous tests when unstained, was extensively damaged by the furniture carpet beetle when stained with tomato juice and human urine.

Conclusions.—Clothes moth larvae, whether large or small, are definitely attracted to certain common stains. Small larvae of the furniture carpet beetle are also attracted to such stains. The small larvae of the black carpet beetle show a lesser attraction to common stains than the small larvae of the furniture carpet beetle. The large larvae of the furniture carpet beetle are less attracted to stains than the large larvae of the webbing clothes moth. The large larvae of the black carpet beetle are not attracted by any of the common stains tested.

From this we can conclude that cleaning or washing of woolens to rid them of stains will discourage feeding by the larvae of the webbing clothes moth and small larvae of the furniture and black carpet beetles. Large larvae of the black carpet beetle will feed on woolens whether they are stained or not, and to a lesser extent this is true of large larvae of the furniture carpet beetle. In order to protect clean woolens from feeding by fabric pests, the woolens should be treated with mothproofing sprays or protected by other means.

Previous tests have shown that the webbing clothes moth, the black carpet beetle, and the furniture carpet beetle do not feed on clean fabrics made from Orlon, Dynel, and Dacron. Under starvation conditions, the carpet beetles may slightly damage clean nylon fabrics. Orlon and Dynel were not eaten by any of the three fabric pests when these fabrics were stained with three stains highly attractive to the fabric pests, namely, tomato juice, human urine, and human sweat. Under starvation conditions, the furniture carpet beetle extensively damaged stained areas of nylon and Dacron. The black carpet beetle under starvation conditions fed extensively on nylon stained with human sweat.

Observations on the webbing clothes moth and the furniture carpet beetle showed that the life cycles of these insects were greatly accelerated by stains from tomato juice on woolen cloth.

Table 3.—Feeding on stained synthetic fabrics exposed for 28 days to large larvae of the webbing clothes moth, black carpet beetle, and the furniture carpet beetle.

Insect	Fabric	Feeding on Stain		
		Tomato Juice	Human Urine	Human Sweat
Clothes moth	Orlon	O	O	O
Black carpet beetle	Orlon	O	O	O
Furniture carpet beetle	Orlon	O	O	O
Clothes moth	Dynel	O	O	O
Black carpet beetle	Dynel	O	O	O
Furniture carpet beetle	Dynel	O	O	O
Clothes moth	Nylon	O	O	O
Black carpet beetle	Nylon	O	O	E
Furniture carpet beetle	Nylon	E	E	E
Clothes moth	Dacron	O	O	O
Black carpet beetle	Dacron	O	O	O
Furniture carpet beetle	Dacron	E	E	O

References Cited

Anonymous. 1952. CSMA Textile Resistance Test. Soap and sanitary chemicals, blue book: 259–62, 276.

Colman, W. 1932. Effect of yeast on clothes moth larvae. Jour. Econ. Ent. **25**: 1242.

Billings, S. C. 1936. Notes on clothes moth breeding. Jour. Econ. Ent. **29**: 1014–1016.

Fraenkel, B., and M. Blewett. 1945. The dietetics of the clothes moth, *Tineola bisselliella* Hum., Jour. Exptl. Biol. **22**: 156–61.

Heal, R. E. 1942. Evaluating protection of fabrics from clothes moth and carpet beetle attack. Jour. Econ. Ent. **35**: 249–55.

Mallis, A., A. C. Miller, and R. C. Hill. 1958. Feeding of four species of fabric pests on natural and synthetic textiles. Jour. Econ. Ent. **51**: 248–49.

Pink Bollworm Resistance in Cotton[1]

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Abstract

Experiments were conducted during 1953–55 at College Station, Texas, to determine if selected species and varieties of cotton were resistant to pink bollworm (*Pectinophora gossypiella* (Saund.)) damage. Results of these experiments indicated that *Gossypium thurberi* was resistant to pink bollworm attack. The mechanism of resistance appeared to be preference of the moth for other cottons for oviposition. Evaluation of the various experiments indicated that this nonpreference for *G. thurberi* was caused by morphological characters of tight smooth calyx, spike-like flared bracts and glabrous vegetative parts of the plant. A cross of Stoneville 2B × *G. tomentosum* showed a high degree of antibiosis to pink bollworm larvae. Hexaploid Z-64 and *G. thurberi* and *G. herbaceum* exhibited antibiosis to lesser degrees. No evidence of resistance was noted in the Old World species of *G. arboreum* and *G. herbaceum*.

Results obtained in the various experiments conducted indicated that modification of certain morphological characters of the cottom plant may result in better control of the pink bollworm. The use of a cotton that has flared or deciduous bracts, tight smooth calyxes, and more pubescence on the vegetative parts should result in most of the eggs being laid on the vegetative parts. Higher natural mortality and increased effectiveness of applications of insecticides should result from the increased exposure of the pink bollworm larvae.

As a result of the continued spread of the pink bollworm in Texas, research has been intensified in an effort to develop additional control measures to supplement cultural practices mainly relied upon at present. The research reported herein is concerned with the resistance of cotton to damage by the pink bollworm.

Painter (1951) pointed out that crop plants resistant to insect damage has been a matter of record for over 100 years. Some insects currently controlled principally by resistant varieties of host plants include the grape phylloxera, hessian fly on wheat and Jassids on cotton. Reports of resistance in cotton to pink bollworm damage, especially among Old World species, have appeared in the literature for over 40 years. An excellent review of this subject is given by Painter (1951).

Many of the earlier reports of pink bollworm resistance in cotton were based on field observations. Chapman (1937, 1938, 1941) reported no resistance in several commercial varieties of upland cottons. He did find that the early-maturing varieties escaped much of the heavy late-season pink bollworm damage. Squire (1939) conducted experiments to determine the nature of resistance apparent in edible okra, *Hibiscus esculentus* L. and attributed the plant resistance to slime killing the first instar larvae. When bolls of *Gossypium trilobum* (Thurberia) and Sea Island cotton were infested with eggs, approximately the same number of larvae entered the bolls of each cotton, but none developed on *G. trilobum*. Husain & Khan (1940) conducted cage and field plot tests to compare the susceptibility of *G. hirsutum* L. cottons with *G. arboreum* L. varieties. They found the indigenous *G. arboreum* varieties contained significantly fewer pink bollworm larvae per boll than the imported upland cottons. Knight (1944) working in the Anglo-Egyptian Sudan initiated a breeding program to transfer apparent pink bollworm resistance of *G. thurberi* Todaro and *G. armourianum* Kearney to commercial cottons. Most of the published reports of the Experiment Stations of the Empire Cotton Growing Corporation in the Anglo-Egyptian Sudan since 1944 contain reports of the progress made in this program.

Results of greenhouse and field plot experiments are reported herein. All available species of *Gossypium* were included in the tests in order to cover a wide range of variability of cottons for possible sources of resistance. *G. thurberi* and the Asiatic species *G. arboreum* and *G. herbaceum* L. were given special attention because of references to them in literature as being resistant to pink bollworm.

Greenhouse Screening Experiment.—Among the 139 species and varieties of cottons planted, an adequate number of bolls was obtained from 108 of them for comparative studies with a standard cotton in greenhouse screening tests for resistance to pink bollworms. The investigation covered a period of 2 years.

Methods.—The cottons were planted in 1-gallon pots and held on benches inside the greenhouse throughout the period of the experiment. All blooms were tagged daily and dated in order that bolls of the same age range might be tested. By using tags of the same color during each 10-day period, bolls of the same age range could be identified easily for infestation and collection. The bolls were infested individually with five viable pink bollworm eggs when 10 to 20 days of age. Pink bollworm eggs were obtained by placing moths in an oviposition cage so that they would oviposit through screen wire onto a cotton leaf. The eggs were collected with a moist camel's-hair brush and transferred in groups of five to the carpel sutures along the distal end of the cotton boll. The infested bolls were removed from the plant for examination 10 days after infestation, when they were 20 to 30 days of age. After the calyx and bracts were removed, each boll was weighed and carefully examined for entrance holes in the carpels and larvae in the boll. Deltapine 15 was used as a standard.

Results.—Mean boll weights of the cottons included in the experiment ranged from 0.3 gram to over 20 grams per boll. The use of five eggs per boll, regardless of boll size, resulted in the small bolls being infested with more larvae than could be supported, whereas the large bolls could have supported a larger number of larvae. When the number of larvae recovered per gram of boll weight was plotted against mean boll weight, a curvilinear relationship was obtained with the larger values of larvae recovered from the smaller bolls, figure 1. Group compari-

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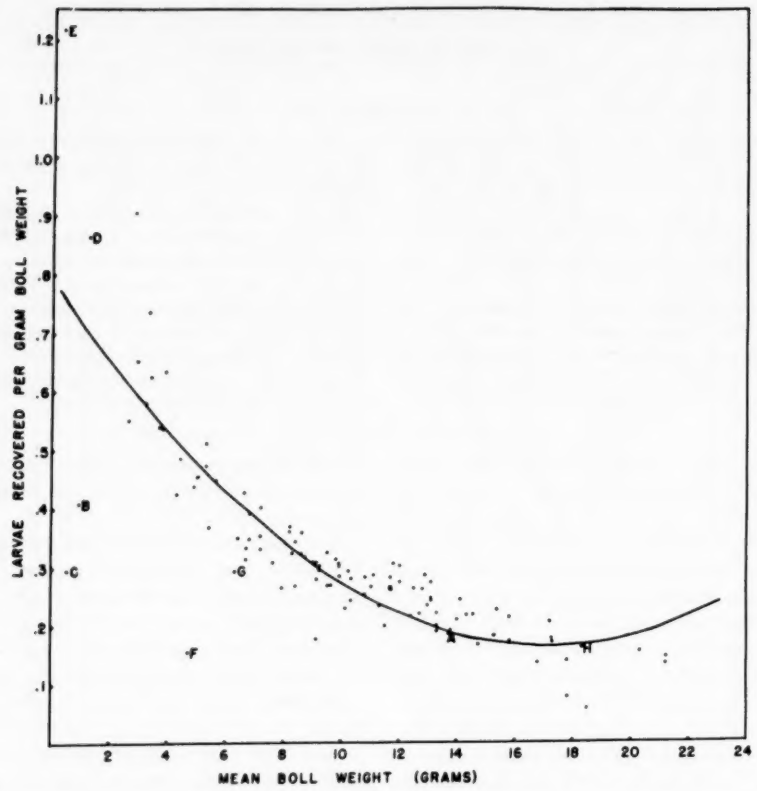

FIG. 1.—Regression of number of larvae recovered per gram of boll weight on mean boll weight for 108 cottons in greenhouse screening experiment for resistance to pink bollworm damage, College Station, Texas, 1954–1955: (A) Deltapine 15, (B) *G. thurberi*, (C) Texas 389, (D) MW-298, (E) *G. stocksii*, (F) Stoneville 2-B×*G. tomentosum*, (G) Hexaploid Z-64, (H) MW-147.

sons of larvae recovered per gram of boll weight were made for each cotton with the standard, but the results were distorted by the differences in boll size. Therefore, the regression is the most valid test of these data for evidence of resistance. Based on their position below the regression line, three varieties of cotton appeared to possess some degree of antibiosis to pink bollworm larvae. The most outstanding of these cottons was a cross of Stoneville 2B×*G. tomentosum* (F). Stoneville 2B is a variety of *G. hirsutum*, and *G. tomentosum* Nuttall is a wild tetraploid cotton found in Hawaii. *G. thurberi* (B) and Texas 389 (C)—variety Marie-galante of *G. hirsutum*—also fall well below the regression line, indicating some degree of resistance. However, analysis of the variability within samples of the four cottons with boll weights below 2 grams indicated highly significant differences of individual boll records of these cottons compared with Deltapine 15. This evidence would lead one to suspect the apparent resistance indicated here of the very small bolled cottons as being doubtful because of the high degree of variability within samples of very small cotton bolls.

Results of another test that was used to compare the relative susceptibility of cottons to pink bollworm damage are given in figure 2. The percentage of larvae that survived of those that entered each boll was plotted against mean boll weight. Again, the Stoneville 2B×*G. tomentosum* cross shows greatest resistance. Of the small-bolled cottons, *G. thurberi* (B), *G. stocksii* (E) and MW-298 (D)—race Palmeri of *G. hirsutum*—contained a low percentage of the larvae that entered the bolls. Marie-galante (C) which appeared resistant in figure 1, contained a relatively high percentage of the larvae that entered the bolls. *G. stocksii* and MW-298 contained very large numbers of larvae per gram of boll weight. Based on the results of these two tests the Stoneville 2B×*G. tomentosum* cross appeared to possess a high degree of antibiosis to pink bollworm larvae, and *G. thurberi* was resistant to a lesser degree. Another cotton that was not outstanding in either test for resistance, but was quite consistent in having low values in each case was a hexaploid (G), figures 1 and 2, resulting from the colchicine-treated cross of *G. hirsutum*, variety Mebane, ×*G. arboreum*, variety Nanking.

FIELD PLOTS EXPERIMENTS.—Field plot experiments designed to evaluate antibiotic properties as well as preference of the insect for various cottons were conducted in 1954 and 1955. Cottons were selected for these tests that fruit under field conditions at College Station.

Procedure.—Two field plot experiments were conducted in 1954. One included 40 varieties of upland cotton and *G. thurberi* and the other 34 varieties of upland and *G. thurberi*. One experiment was conducted in 1955 that included *G. thurberi* and Pima (*G. barbadense*). Deltapine 15 was included in all experiments as a standard.

The cottons were planted in the greenhouse in 5-ounce paper drinking cups filled with a mixture of 50% fine gravel and 50% humus. When in the 4- to 6-leaf stage, the cottons were transplanted to plots in the field. The

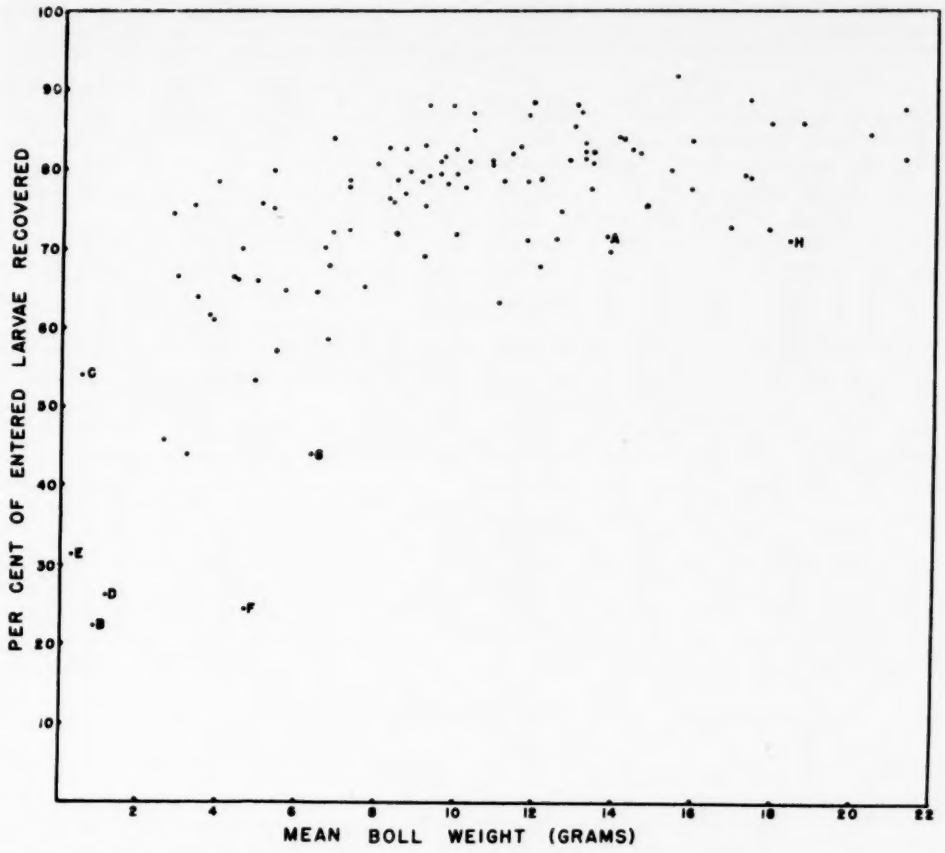

FIG. 2.—Percentage of survival of larvae that entered bolls on mean boll weight for 108 cottons in greenhouse screening experiment for resistance to pink bollworm damage, College Station, Texas, 1954–1955: (A) Deltapine 15, (B) *G. thurberi*, (C) Texas 389, (D) MW-298, (E) *G. stocksii*, (F) Stoneville 2-B×*G. tomentosum*, (G) Hexaploid Z-64, (H) MW-147.

plots were two rows wide and 36 feet long (1/200 acre). The plants were randomized in each plot and covered with a 6′×6′×36′ cage. The cover of the cage was constructed of 14×18 mesh plastic screen. The 1954 experiments were replicated four times with one plant of each cotton in each replicate. In 1955 the experiment was replicated five times with six plants of each cotton included in each replicate.

Pink bollworm infestations in the plots were obtained by introducing approximately 150 moths into each cage at 10-day intervals beginning 13 days before the first boll collection. Boll collections were made at 10-day intervals as long as the cotton fruited. The blooms were tagged with different colored tags for each 10-day period as described for the greenhouse test. Bolls were collected for examination when 20 to 30 days of age. After the bracts and calyx were removed, each boll was weighed and records made of the number of entrance holes present and of larvae recovered.

Results.—Samples of 25 or more bolls were obtained for 54 upland varieties, *G. thurberi* and the Deltapine 15 standard in the 1954 experiments. In the 1955 experiment samples of 50 or more bolls were obtained for the three cottons tested. The criteria used as an indication of resistance in these experiments were the number of larvae recovered per gram of boll weight and percentage of bolls escaping injury. Only the cottons that were significantly different from the standard in either of these categories were included in table 1. In experiment 1, 1954, the bolls of Texas 42 contained significantly fewer larvae than the standard. All other cottons listed under this experiment, table 1, contained significantly more larvae than the standard. A comparison of the entrance holes per boll and the mean boll weight of Texas 42 with the other cottons indicated that this cotton had a lower pink bollworm infestation than the standard. Since the greenhouse experiment with this cotton indicated no antibiosis, the apparent resistance in this case may have been the result of bolls escaping oviposition because of the preference of the moth for other cottons for oviposition.

In experiment 2, 1954, *G. thurberi* bolls contained significantly fewer larvae than the standard. In experiment 1, 1954, this cotton contained a relatively small number of larvae compared with the standard, but not low enough for significance. The entrance holes per boll were higher in experiment 1 than experiment 2 for *G. thurberi*, indicating the infestation level was lower on this cotton in experiment 2. This could explain the significant difference in the number of larvae recovered in one test as compared with the other. There were no significant differences in number of larvae recovered in the 1955 experiment.

The most striking result of these experiments was that

Table 1.—Larvae recovered and bolls that escaped injury by the pink bollworm in field cage experiments in 1954 and 1955 at College Station, Texas.

Variety of Cotton	Total Bolls	Entrance Holes per Boll	Larvae Recovered per Boll	Mean Boll Weight in Grams	Larvae Recovered per Gram of Boll Weight	Bolls Escaped	
						No. Bolls	Per Cent
			Experiment 1—1954				
Deltapine 15	117	12.8	6.0	12.7	0.4921	5	8.54
G. thurberi	298	2.3	0.3	0.8	0.3888	65	31.48**
Texas 3	60	24.4	9.4	11.7	0.8084**		
Texas 24	72	19.0	8.6	11.6	0.7781**	1	2.27
Texas 42	44	9.3	4.8	15.7	0.2929*[a]	3	6.62
Texas 49	87	20.8	9.0	12.5	0.6971*		
Texas 62	61	14.1	6.1	8.2	0.7054*		
Texas 105	62	24.3	8.2	13.4	0.7390*	1	2.61
Texas 108	37	18.3	7.8	11.1	0.7056*	1	4.03
Texas 109	87	21.6	9.6	11.6	0.8360**		
Texas 160	77	19.4	8.2	10.6	0.7709**		
Texas 161	25	18.1	7.4	11.8	0.8246**		
Texas 183	119	19.2	8.7	13.5	0.6835**		
L.S.D. at 5% level					0.1868		
at 1% level					0.2474		19.86
			Experiment 2—1954				
Deltapine 15	88	21.5	8.8	13.8	0.6295	1	2.81
G. thurberi	180	1.1	0.2	1.0	0.1890**[a]	76	38.39**
Texas 398	83	7.9	3.9	4.1	0.9388*	2	4.03
Texas 399	83	10.9	5.3	5.3	1.0531**	4	5.90
Texas 402	76	9.4	4.7	4.6	1.0075**	1	3.86
L.S.D. at 5% level					0.2652		
at 1% level					0.3522		19.88
			Experiment 1—1955				
Deltapine 15	233	24.1	8.7	15.3	0.5678	1	2.13
G. thurberi	642	3.1	0.6	1.0	0.6883	51	16.21**
L.S.D. at 1% level							10.43

[a] Significantly fewer larvae recovered per gram of boll weight than for Deltapine 15.

highly significant numbers of *G. thurberi* bolls escaped pink bollworm injury in all experiments. This was outstanding in the 1955 experiment in which the insect infestation was higher than in the other experiments. The number of entrance holes per boll increased, table 1, as the number of larvae recovered per gram of boll weight increased. As these two values increased, the percentage of bolls escaping oviposition decreased. This indicated that the number of larvae recovered from the bolls of this cotton varied with the insect infestation and that many bolls escaped because they were not exposed to the larvae. This could be the result of the insect's preferring to oviposit on cottons other than *G. thurberi*.

Oviposition Experiments.—Experiments were conducted in 1954 and 1955 to determine the effect of various structural differences of cottons on oviposition habits of the pink bollworm. The pink bollworm moth does not normally oviposit on an open smooth area. Therefore, the morphological properties of various cottons, *viz.*, pubescence, type of bracts and calyx, size of ribs on the leaf blade and others might be important in stimulating oviposition.

Procedure.—The following cottons with the indicated morphological characteristics were tested. Deltapine 15 was used as the standard. Deltapine 15 has normal foliaceous bracts, and the outer margin of the calyx is convoluted. There is a moderate amount of pubescence on the vegetative parts, especially the growing terminals. Pima (*G. barbadense*) has large foliaceous bracts which completely enclose the boll and a tight smooth calyx along the outer margin. The younger leaves have scattered leafhairs. The ribs of the leaf blade are heavy and form acute

Table 2.—Site of oviposition of pink bollworm on Deltapine 15 and *G. thurberi* bolls at College Station, Texas, 1954.

Variety	Under Calyx		On Boll[1]		Below Bract[2]		Total		Eggs Per Boll	Bolls Escaped	
	No. Eggs	Per Cent	No. Eggs	Per Cent	No. Eggs	Per Cent	Eggs	Bolls		No. Bolls	Per Cent
					Test 1						
Deltapine 15	419	56.4	315	42.4	9	1.2	743	38	19.6	2	5.3
G. thurberi			137	100.0			137	110	1.2	87	79.1
					Test 2						
G. thurberi	8	2.3	347	97.7			355	85	4.2	45	52.9

[1] Eggs found inside the bracts but not under the calyx.
[2] Eggs found below the bracts around the nectaries.

angles with the midrib. *G. thurberi* has slender, spike-like, flared bracts and a tight smooth calyx along the outer edge. The vegetative parts are almost devoid of pubescence. *G. herbaceum* has normal foliaceous bracts that flare outward and expose the cotton boll entirely. Frego bract has twisted, distorted and slightly reduced bracts. Texas 536 has very slender, deciduous type bracts. The leaves are narrowed and distorted, giving the plant the appearance of having suffered from 2–4D damage. The last three cottons have calyx and vegetative characteristics similar to Deltapine 15 except as indicated. Various combinations of these plants were randomized in 6′×6′×36′ screen cages. Approximately 150 pink bollworm moths were released in each cage after the plants had started fruiting. The plants were collected 5 days after infestation and examined for number and site of eggs on the vegetative and fruiting parts. All plants collected for examination contained approximately the same amount of vegetative growth.

Results.—Results of two experiments conducted in 1954, in which only the cotton bolls were examined for pink bollworm eggs, are presented in table 2. No eggs were found under the calyx on *G. thurberi* bolls in experiment 1. The eight eggs found in this location on the bolls in experiment 2 were found on two bolls in which the calyx was split and distorted. Caging moths on *G. thurberi* resulted in an increase in the number of eggs found per boll, but still a very high percentage of the bolls were devoid of eggs.

Results of seven experiments with various combinations of cottons tested in 1955 are given in table 3. In experiment 1, a higher percentage of the eggs were laid on the fruit of *G. herbaceum* than on the standard. Of the eggs on the fruit of *G. herbaceum*, 97% were under the calyx compared with 61% in the same location for Deltapine 15. Thus, the flared bracts of *G. herbaceum* resulted in a greater percentage of the eggs being placed in the protected position under the boll calyx. In experiments 2, 3 and 4 the bolls of Pima were not over 3 weeks of age. In these experiments the percentage of eggs on the vegetative parts of the plant was much higher than on the fruit. The opposite was true for the standard. Pima bolls 3 weeks of age have a tight smooth calyx that apparently prevents the moth from inserting the ovipositor under the calyx. In the older Pima bolls, experiments 5 and 6, the calyx became split and distorted because of the increased circumference of the boll. This resulted in more eggs being laid on the fruit. Most of the eggs on the vegetative parts of Pima were found in the acute angles formed by the heavy leaf veins at the point where they radiate out from the pedicule. Texas 536 had no eggs on the vegetative parts. Apparently the smooth, distorted foliage of this cotton was undesirable for oviposition.

In experiment 7 the fruit was removed from Deltapine 15 and Pima, but not from *G. thurberi*. The results indicated that the vegetative parts of Deltapine 15 and Pima were preferred for oviposition to the fruit of *G. thurberi*. In all experiments the relative number of eggs found on *G. thurberi* was much less than for the other cottons.

REFERENCES CITED

Chapman, A. J. 1937. Varietal resistance (to pink bollworm). Texas Agric. Expt. Sta. Ann. Rept. **50**: 62–63.

Chapman, A. J. 1938. Pink bollworm. Texas Agric. Expt. Sta. Ann. Rept. **51**: 44.

Chapman, A. J. *et al.* 1941. Cotton varieties. Texas Agric.

Table 3.—Comparison of the number of pink bollworm eggs deposited on vegetative parts or on fruiting parts of cottons with various morphological differences in 1955 at College Station, Texas.

Variety of Cotton	No. Plants	Vegetative Parts		Fruiting Parts		Total Bolls Counted	Eggs per Boll	Total Eggs
		No. Eggs	Per Cent	No. Eggs	Per Cent			
				Test 1				
Deltapine 15	10	440	25.2	1,309	74.8	103	17.0	1,749
G. herbaceum	10	247	17.5	1,163	82.5	106	13.2	1,410
Frego bract	4	135	24.2	424	75.8	21	20.2	559
				Test 2				
Deltapine 15	5	258	33.3	517	66.7	40	19.4	775
Pima	5	220	58.8	154	41.2	47	8.0	374
				Test 3				
Deltapine 15	6	282	20.0	1,128	80.0	57	19.8	1,410
Pima	6	478	62.0	293	38.0	55	5.3	771
				Test 4				
Deltapine 15	3	35	26.3	98	73.7	20	4.9	133
Texas 536	6			237	100.0	33	7.2	237
Pima	10	395	63.5	227	36.5	118	1.9	622
				Test 5				
Deltapine 15	6	372	18.7	1,616	81.3	43	17.6	1,988
Pima	6	1,482	50.6	1,448	49.4	42	34.5	2,930
G. thurberi	6	188	72.3	72	27.7	102	0.7	260
				Test 6				
Deltapine 15	5	327	26.2	923	73.8	45	20.5	1,250
Pima	5	261	31.6	566	68.4	34	16.6	827
G. thurberi	6	41	33.6	81	66.4	236	0.4	127
				Test 7				
Deltapine 15	5	257	100.0	No fruit[1]				257
Pima	5	408	100.0	No fruit[1]				408
G. thurberi	10	56	30.5	128	69.5	159	0.8	184

[1] Fruit removed from the Deltapine 15 and Pima.

Expt. Sta. Ann. Rept. **54**: 35.

Husain, M. A., and M. H. Khan. 1940. Studies on *Platyedra gossypiella* Saunders in the Punjab. IV. Relative incidence on exotic and indigenous varieties of cotton. Indian Jour. Ent. **2**: 45–57.

Knight, R. L. 1944. Progress report of the Shambat Substation, Anglo-Egyptian Sudan. Empire Cotton Growing Corp. Rept. Expt. Stas. **1942-43**: 73.

Painter, R. H. 1951. Insect resistance in crop plants. The MacMillan Co., New York. 520 pp.

Squire, F. A. 1939. A note on the resistance of *Hibiscus esculentus* and *Gossypium trilobum* to *Platyedra gossypiella* Saund. Empire Cotton Growing Rev. **16**: 268–71.

Laboratory Studies of Feeding and Oviposition Preferences of *Anthonomus grandis* Boh.[1]

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ABSTRACT

Boll weevils (*Anthonomus grandis* Boh.) were offered the choice of flower buds from two strains of Upland cotton, Strain #50 which carries the normal complement of resin glands and two genetic factors for hairiness, and Strain #6 which is completely glandless and has glabrous buds. Weevils found buds of Strain #50 more readily than those of Strain #6, this preference being exhibited both in continuous light and in dark conditions, and also being unaffected by removal of the conspicuous bracteoles. There was no significant difference in the ability of the weevils to feed and oviposit on the two strains when no choice was offered, but with choice available the weevils showed a marked feeding preference in favor of Strain #6 and, on the contrary, a preference in favor of Strain #50 for oviposition. The feeding preference became weaker as the food supply was used up. The following provisional interpretation of these results is suggested. The presence of glands is an important factor in attracting the weevils to the cotton plant, and probably is of importance in stimulating oviposition. Glands have little effect on feeding. Hairiness of the flower buds discourages feeding when an alternative choice of glabrous buds is available.

In an earlier paper (Stephens 1957) it was suggested that certain genetic mutants in cotton which control plant hairiness, color and absence of resin glands, might provide useful tools for the analysis of the boll weevil's feeding and oviposition reactions. Later, Wannamaker (1957) and Wessling (1958a, 1958b) showed that types carrying the hairy mutants, H_1 and H_2, in homozygous condition were less subject to boll weevil attack than their "normal" sibs. Wessling also found that the resistance associated with H_1 and H_2 in combination was greater than with either separately. The chief effect of increased hairiness was to discourage oviposition—there was little indication that feeding was affected.

Wessling (1958b) found that the mutant, R_1, responsible for red anthocyanin coloration in the vegetative parts of the plant was associated with resistance which was enhanced in combination with H_2. A fourth mutant, *gl*, was also investigated. Since this mutant is associated with absence of resin glands from stems, leaf veins and bolls, and it is known (Stanford & Viehover 1918) that the secretions of these glands have a characteristic odor, it was thought possible that glandless plants might be less attractive to the weevil. Unfortunately in this mutant form the glands on the surface of the flower bud (*i.e.*, the important site for feeding and oviposition) were very little reduced. Wessling (1958b) was unable to detect any significant effect of *gl* on oviposition. Recently Dr. S. C. McMichael has developed a completely glandless strain at the U. S. Department of Agriculture Cotton Field Station, Shafter, California. Through the courtesy of the U. S. Department of Agriculture Cotton Research Branch this strain was made available for the experiments to be presented later in this paper.

The studies reported so far show that certain characters which acting separately produce only a low level of resistance can rather easily be built into effective combinations which exhibit a high level of resistance. It seems likely that genes associated with varied but low level preferences would be much more common in plant populations than "major" mutants capable of producing high level resistance or immunity in one step. The latter when found are extremely valuable to the plant breeder, but the small number of insect resistant varieties which have been developed does not suggest that they are very common. Since preference depends on the insect's sensory responses to the host plant, it is convenient for the purpose of experiment to consider them in three hypothetical time sequences. First there is a "seeking response" (presumably visual and/or olfactory) which enables the insect to locate a suitable host plant. Second there is a "feeding reponse" (visual, olfactory, tactile?) which enables the insect to locate a favorable site and commence feeding. Third there is an "oviposition response" (visual, olfactory, tactile?) which enables the female insect to locate a suitable site for oviposition. Clearly these three sequences may be conditioned by quite different combinations of sensory stimuli, and experiments have to be devised to test them separately. By offering alternative choices during each sequence, it may be possible to analyze the nature of the more important preferences, and (hopefully) to synthesize combinations which provide "sensory blocks" in each time sequence.

The experiments described herein were based on the

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foregoing hypothetical scheme. Since they were carried out under highly artificial laboratory conditions, their results cannot be extrapolated to apply to natural but more complex situations in the field. However they do provide important information on the operation of preference mechanisms.

EXPERIMENTAL.—The experimental material available for study consisted of two genetic strains of Upland cotton. One of these (#50) was homozygous for both hairy mutants, H_1 and H_2, and was derived from the H_1H_2 combination reported previously by Wessling (1958b). The flower buds and bracteoles have normal resin glands. The other (#6) was the completely glandless strain developed by McMichael which has been mentioned earlier in this paper. In this strain the flower buds are completely glabrous.

Experiment 1A. Preference Associated with the Seeking Response.—The object of this experiment was to discover if there was any difference in the ability of the boll weevil to find flower buds of the two strains under test and to attempt to determine the nature of the seeking response.

Tests were carried out in cages normally used for studies of experimental *Drosophila* populations. These are lucite boxes (18″×5″×4″). One end of the cage has a stoppered hole through which the insects are admitted; in the other end the lucite wall is replaced by a fine gauze screen for ventilation. The floor of the cage is fitted with 16 removable plastic food cups arranged in two parallel rows of eight. Five freshly picked and undamaged flower buds of either #6 or #50 were placed in each cup—eight cups of each strain. As far as possible the buds from each strain were matched for size, so that approximately the same range of size was available in each strain. The strains were distributed in pairs along the length of the cage, the position ("left" or "right") in each pair being randomized. Forty weevils (sex undetermined) which had emerged from pupae within 3 to 4 days prior to the experiment were enclosed in a dark glass vial which replaced the stopper at the end of the cage. The weevils were then free to crawl into the cage and locate the flower buds. It will be noted that the total number of flower buds available in the cage provided one bud of each strain per weevil.

Sixteen cages were assembled in this fashion in an air-conditioned room (temperature c 25° C). Eight of the cages were set up under continuous light from a fluorescent source overhead, and eight under continuous darkness. Each group, "light" or "dark," was again divided into subgroups of four cages. In one subgroup the bracteoles surrounding the flower buds were left intact (*i.e.*, as "squares"); in the other subgroup the bracteoles were removed. The object of these treatment groupings was to investigate the importance (if any) of visual stimulation in the seeking response.

In 2 or 3 hours most of the weevils had settled in the cups, and as will be shown later, little further movement outside each cup occurred. After 20 hours the cups were removed and the number of weevils present in each cup was counted. At the same time the total number of feeding punctures on the five buds in each cup was recorded.

The shape of the cage was not entirely satisfactory for an experiment of this type because there was a marked tendency for the weevils to accumulate in the cups at the end of the cage farthest from the entrance. A smaller accumulation of weevils occurred in the cups nearest the entrance, and the cups in the middle of the cage were often unvisited. This nonrandom distribution occurred both in the "light" and "dark" groups and was not associated strongly with the phototropic response of the insect. Since a nonrandom distribution is not satisfactory for statistical analysis, the individual cup counts were pooled into proximal and distal groups of eight cups each, according to their position relative to the cage entrance. The unit for statistical analysis was therefore 4 cups, on which was superimposed the effects of 2 strains, 2 positions, 4 treatments (2 light×2 bracteole) with 4 replications within each treatment, making a total of 64 units.

Table 1.—Numbers of weevils finding flower buds of two strains of cotton under different treatments.[a]

	DARK		LIGHT		
	Bracts Present	Bracts Absent	Bracts Present	Bracts Absent	TOTAL
Strain #50	66	88	81	80	315
Strain #6	76	42	52	51	221
Total	142	130	133	131	536
"t"	0.606	3.195	3.015	2.318	2.497
P	0.50–0.60	0.01–0.02	0.02–0.05	0.05–0.10	0.01–0.05

[a] In each treatment, 160 weevils were tested.

Results.—An analysis of variance of the data showed that only one component—the effect of strain differences—was significant when compared with the "within treatment" component serving as an "error" term in the analysis. The total numbers of weevils finding flower buds of the two strains under the four different treatments are summarized in table 1 together with "t" tests of differences between strains (calculated separately for each treatment). Under three of the four treatments there was a marked tendency for more weevils to be attracted to Strain #50 than to Strain #6. The apparent reversal of this tendency in the remaining treatment was quite insignificant. It may be concluded that boll weevils are able to locate flower buds of Strain #50 more readily than Strain #6 under a variety of external conditions. Since this ability is expressed as readily in complete darkness as under continuous illumination it is evident that visual stimuli are unimportant, and the fact that the buds of Strain #50 contain resin glands which are absent from Strain #6 suggests that the main factor in the seeking response is an olfactory attraction.

Experiment 1B. Preference Associated with the Feeding Response.—The same experiment which has been described above also provided information on feeding ability as measured by counts of feeding punctures. Since the number of feeding punctures per unit would clearly be influenced by the number of weevils located in each unit a direct analysis of the data would provide no useful information. However, by the usual covariance analysis, the effect of differences in numbers of weevils can be removed, and the adjusted variances of feeding punctures analyzed.

The biological validity of the covariance adjustment rests on the assumption that the weevils located in each cup were to a major extent responsible for the feeding punctures found in that particular cup. If weevils moved freely from cup to cup this assumption would be invalid. Four independent lines of reasoning favor the view that while some movement occurred, the majority of the

Table 2.—Numbers of feeding punctures on flower buds of two strains of cotton under different treatments.[a]

Strain No.	Dark		Light		Total
	Bracts Present	Bracts Absent	Bracts Present	Bracts Absent	
50	231 (228)	368 (441)	226 (275)	185 (230)	1010 (1174)
6	197 (228)	299 (212)	194 (142)	212 (156)	902 (738)
Total	428 (456)	667 (653)	420 (417)	397 (386)	1912 (1912)

[a] The numbers shown are adjusted for the numbers of weevils feeding: the corresponding numbers before adjustment are given in parenthesis below each entry.

Main Effects	"F"	P
Strains	1.0577	>0.20
Light	7.7376	0.001–0.01
Bracts	4.6420	0.01 –0.05

weevils remained in the cups after they had commenced feeding. First, the length of the experiment was deliberately restricted to 20 hours, during which time interval the average number of punctures produced per weevil was 3.6 (less than the number of flower buds available per cup). Exhaustion of food supply which might have been a factor in encouraging movement was therefore not operative in this experiment. Second, over 83% of the weevils introduced into the cages were found in the feeding cups when the cages were examined. Weevils outside the cups were usually static—either they had failed to enter, or were resting at the top of the cage. Third, inspection of the original data showed a high correlation ($r = +0.80$) between the number of weevils and the number of feeding punctures per unit. If the weevils had moved freely between cups a correlation of this magnitude would be unlikely. Finally the fact that cups toward the middle of each cage frequently contained no weevils provided a direct indication of the amount of movement. If no movement from cup to cup occurred, cups with no weevils should have no feeding puctures. Actually out of 73 cups which contained no weevils, over half (41) had no punctures and the remaining 32 had an average of less than 2 punctures each, as compared with a general average of 7.5 punctures per cup. From these considerations it seems reasonable to conclude that a covariance adjustment is an appropriate method of analyzing the data.

Results.—Analysis of the adjusted variances in feeding punctures showed no significant difference between strains, though there was a marked effect of treatments. There were no significant interactions between strains and treatments. Table 2 summarizes the total numbers of feeding punctures found in the two strains under the four treatments. In this table the main entries are the adjusted totals—the corresponding figures prior to adjustment are enclosed in brackets below each entry. At the foot of the table are given the "F" values for strain and treatment variances. Feeding in the "dark" treatments was consistently greater than feeding in the corresponding "light" treatments. The removal of the bracteoles also favored feeding. In three of the four comparisons in table 2 in which the effects of presence or absence of bracteoles is contrasted, bracteole removal resulted in more feeding. However, since there were no significant interactions between strains and treatments these treatment effects are of minor interest for the main purpose of the experiment.

Experiment 2. The Effect of "Choice" on Feeding and Oviposition Responses.—The results of Experiments 1A and 1B have shown that weevils found flower buds of Strain #50 more readily than those of Strain #6, but that once the buds were located there was no significant difference in their ability to feed on the two strains. However, since these experiments were terminated before the food material in the cups was in short supply no information was available concerning the behavior of the weevils when forced to move to fresh feeding sites. The fact that they were able to feed on either strain to about the same extent when no "choice" was provided does not imply that no preference would be exhibited under conditions in which both strains were equally available. In order to explore the possible effects of "choice" of feeding and oviposition, a different type of experiment was arranged in which a standard number of weevils was confined with an equal number of flower buds of each strain for a period of 4 days. At the end of this period the weevils had fed on most of the squares and oviposition had begun.

The experiment was set up with 18 one-pint Mason jars fitted with gauze tops for ventilation. In each jar 40 flower buds with bracteoles removed were placed on moist blotting pads. Eight weevils which had been feeding on flower buds for 3 to 4 days prior to the experiment, were placed in each jar. The jars were divided into three groups of six jars each. The first group contained flower buds of Strain #50 alone, the second group flower buds of Strain #6 alone, and the third (mixed) group contained an equal number of flower buds from both strains (20 buds of each strain per jar). The experiment was conducted under the same temperature and light conditions as those used in the "light treatment" already described in Experiment 1. At the end of the 4-day period the number of punctures was recorded in each jar, and each bud was opened to determine whether larvae[2] were present, the number of larvae per jar being recorded.

Results.—The results are presented in table 3. In this table the "t" tests in the "separate" series have to be based on the pooled variances of each strain with 10 degrees of freedom whereas the "mixed" series can be analyzed more precisely on the basis of strain differences

[2] The placement of eggs among the anthers of the developing bud makes accurate egg counts difficult. For this reason larval counts after a period of incubation were preferred. However larval counts suffer from the disadvantage that possible differences in hatchability associated with antibiotic effects of the plant tissues may be confounded with true oviposition preferences.

Table 3.—Comparisons of (A) the number of punctures and (B) the number of larvae produced by weevils on flower buds of two strains of cotton under "separate" and "mixed" tests.

	Strain #50	Strain #6	"t"	P
		A		
Separate	873	844	0.291	0.70 –0.80
Mixed	409	705	3.676	0.01 –0.02
		B		
Separate	70	43	0.972	0.30 –0.40
Mixed	63	22	4.577	0.001–0.01

with 5 degrees of freedom, because the same individual weevils were feeding on both strains.

The feeding comparisons in the upper part of table 3 show that there was no significant difference in the ability of weevils to feed on the two strains separately (*i.e.*, when no "choice" were offered). This agrees with the previous finding in Experiment 1A (see table 2). In the "mixed" series where a "choice" of strains was available, there was a strong preference in favor of Strain #6.

The oviposition comparisons in the lower part of the table show that when no "choice" was available there was no significant difference in the amount of oviposition on each strain as measured by the number of larvae developing. However, the total number of larvae produced on Strain #50 was over 50% greater than on Strain #6. In the "mixed" series there was a highly significant preference in favor of Strain #50.

These results taken at face value apparently indicate a remarkable difference in feeding and oviposition responses; the glandless and glabrous buds of Strain #6 being preferred for feeding, and the hairy buds with normal glands of Strain #50 being preferred for oviposition. But an alternative explanation required investigation. Heavy feeding on the preferred buds of Strain #6 might exhaust the supply of available sites for oviposition, and as a consequence the weevils would be forced to oviposit on the relatively undamaged but nonpreferred buds of Strain #50. Further examination of the data suggests that this alternative explanation is less likely. If a switch from Strain #6 to Strain #50 resulted entirely from a shortage of oviposition sites due to excessive feeding on the former strain, one might expect that very few buds of Strain #6 would remain undamaged by feeding. Again it would be expected that buds of *both* strains which suffered similar feeding damage should have a similar chance of eggs being laid in them. In order to test this possibility the data collected in the "mixed" series of this experiment were regrouped for further analysis. Buds were classified according to the number of punctures they had received into five categories ("none," "1–3," "4–6," "7–9," and "above 10") and the relative numbers of buds with and without larvae in each category for both strains were compared. The results and their analysis are presented in table 4. In all categories there was a consistent tendency for the proportion of buds containing larvae to be higher in Strain #50 than in Strain #6. In the case of the buds with few or no feeding punctures (the first two categories in the table) the difference between the strains is highly significant. It may be concluded that the buds of Strain #50 were perferred sites for oviposition, and that the switch from feeding on Strain #6 to egg-laying on Strain #50 was not entirely a consequence of shortage of oviposition sites on the former strain.

Experiment 3. The Effect of Time on Feeding and Oviposition Preferences.—It is of some interest to know if the preferences which have been demonstrated by the foregoing experiments are rigidly determined or become weaker with time as competition for food and egg-laying sites increases. Unfortunately two experiments designed to test the effect of time on preference were not begun until late August when it was difficult to obtain flower buds and weevils in adequate numbers. Also it was found that oviposition by the weevils available at the time was too erratic to yield reliable results.

Table 4.—Distribution of larvae among flower buds of two strains of cotton, classified into categories according to damage due to feeding punctures.

Feeding Punctures	Without Larvae	With Larvae	Total	χ^2	P
None					
Strain #50	10	14	24		
Strain #6	7	1	8	10.123	0.001–0.01
1 to 3					
Strain #50	24	35	59		
Strain #6	23	9	32	8.086	0.001–0.01
4 to 6					
Strain #50	16	10	26		
Strain #6	25	7	32	1.905	0.10 –0.20
7 to 9					
Strain #50	6	2	8		
Strain #6	24	2	26	1.775	0.10 –0.20
Above 10					
Strain #50	1	2	3		
Strain #6	19	3	22	4.640	0.02 –0.05

The first experiment (Experiment 3A) was essentially a repetition of the "mixed" tests which have been reported under Experiment 2, except that the jars were sampled at daily intervals. Every jar contained six flower buds each of Strain #50 and Strain #6, and six weevils. Competition for food and oviposition sites, as measured by the number of buds available to each weevil, was therefore 2½ times as great as was the case in Experiment 2. Four jars were sampled daily over a 3-day period, making a total of 12 jars examined. At the conclusion of each sampling the weevils were removed from the jars and the buds retained until 5 days had elapsed to allow any eggs laid to develop into larvae. Since no larvae were found the experiment only provided information on feeding preferences.

Results.—The feeding curves on the two strains are shown graphically in figure 1. Each point on the curves is the total obtained from four jars, and the vertical lines measure the 5% confidence limits. The graph shows that feeding proceeded at a greater rate on the buds of Strain #6 for 2 days, after which the rate of feeding on Strain #50 increased sharply. This suggests that as competition for food increased the initial preference in favor of Strain #6 became weaker, forcing the weevils to switch to the nonpreferred Strain #50.

The indication that feeding preference is modified by competition for food was confirmed by a second experiment (Experiment 3B) in which the effect of supplementing the number of flower buds during the course of the experiment was tested. This experiment was set up as before with a total of 12 jars, except that the number of buds available to each weevil was increased (10 buds of each strain plus four weevils per jar). It was hoped that by reducing the competition for food, the weevils might be induced to oviposit. As in the previous experiment, four jars were sampled at the end of the first day and the weevils removed. On the second day the remaining jars were divided into two sets of four jars each. One set was left untouched for an additional 2 days, at the end of

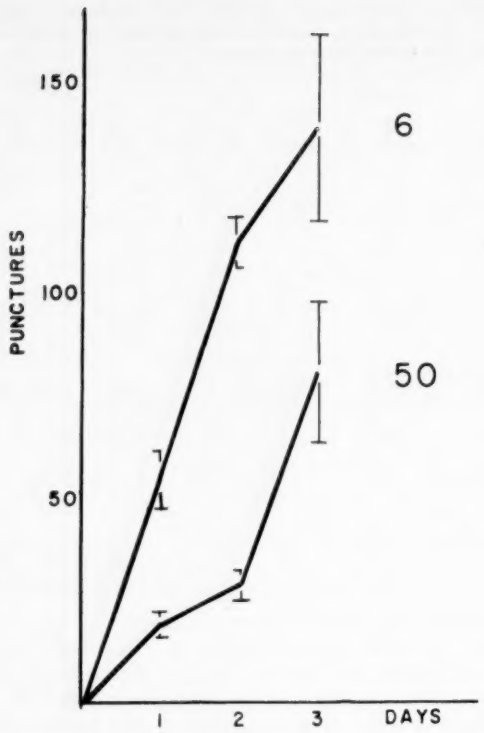

FIG. 1.—Feeding curves obtained when boll weevils are offered the "choice" of equal numbers of flower buds of Strain #50 and Strain #6. Vertical lines indicate the 5% confidence limits for each point on the curves. (Experiment 3A).

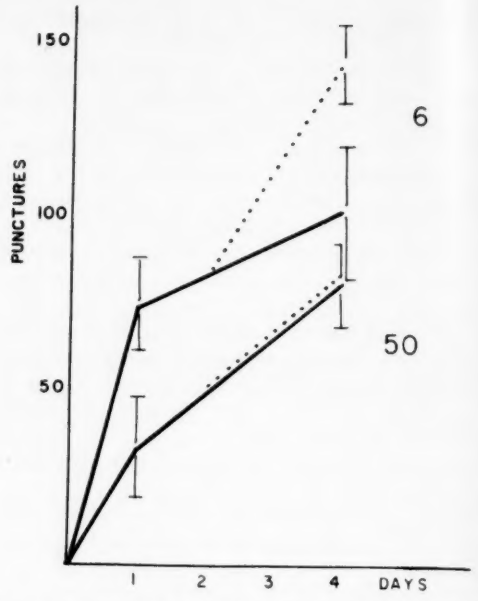

FIG. 2.—Feeding curves obtained when boll weevils are offered the "choice" of equal numbers of flower buds of Strain #50 and Strain #6. The broken lines show the effect of adding supplementary buds of the two strains in equal numbers on the second day. The vertical lines indicate the 5% confidence limits for each point on the curves. (Experiment 3B).

which time the number of punctures was recorded and the weevils removed. To the second set was added an equivalent number of fresh flower buds (10 of each strain) so that the number of flower buds available was doubled without affecting the proportions of the two strains. Punctures in this set were also recorded after an additional 2-day interval, and the weevils removed from the jars. Six days after the beginning of the experiment the buds from all jars were examined for larvae.

Results.—The feeding curves obtained in this experiment are shown in figure 2. The solid lines represent the control series—the broken lines show the effects of adding fresh flower buds during the second day. There is a general similarity between the curves of the control series and those shown in figure 1. Both show a decreasing rate of feeding on Strain #6 with time and a corresponding increase in feeding rate on Strain #50. But following the addition of fresh flower buds, the rate of feeding on Strain #6 was maintained, while feeding on Strain #50 was not altered appreciably. It is clear that the feeding preference is only effective when the food supply is not severely limited.

Very little information could be obtained concerning the oviposition preference. Egg-laying was limited and erratic and there was no increase in the number of eggs laid with time. This suggests that all eggs were laid during the first day and may indicate that the weevils were entering sexual diapause. A total of 15 larvae was obtained from the buds of Strain #50 as compared with five from Strain #6 and the difference was not significant. However, the fact that the majority of the eggs was laid on Strain #50 and the observation that none was laid on Strain #6 after fresh buds were added, support to some extent the evidence presented earlier that the apparent preference in favor of Strain #50 was not attributable to lack of oviposition sites in Strain #6.

Experiment 4. The Mechanism of Feeding Preference Associated with Hairiness.—During examination of buds for feeding punctures it was noticed that the buds of Strain #50 tended to be punctured through the petals above the edge of the calyx, instead of through the calyx as was more usually the case of Strain #6. In flower buds of Strain #50 both petals and calyx are densely hairy, but the petal hairs lie appressed to the contour of the bud, while the calyx hairs do not lie flat. This observation suggested that the depth of the hairy covering rather than hairiness *per se* might be the important factor in determining preference. Accordingly weevils were offered a choice of normal buds of Strain #50 and buds of the same strain in which the calyx had been carefully removed. Treated and control buds were matched for size, and three jars were prepared each containing five buds of each type and five weevils. Although the experiment was extremely limited the results shown in the upper part of table 5 were unequivocal. The treated buds received five times as many punctures as the controls.

Since it might be objected that the removal of the calyx rather than the removal of the hairs which covered it, might be the significant factor, an attempt was made to remove the hairs leaving the calyx intact. It was found that by dipping the buds momentarily in *strong* sulphuric acid, and immediately rinsing them in lime water, the

hairs could be removed leaving a smooth surface. This drastic treatment, of course, killed the calyx tissues—they become suffused with anthocyanin pigment and the contents of the resin glands were exuded. Buds which were rinsed in *weak* sulphuric acid followed by lime water treatment in the same way also became red but the hairs remained undamaged. A series of matched buds were prepared and divided into two groups. One was treated with strong acid, the other with weak acid as described above. The buds were surface dried. Five jars each containing four buds of each group and four weevils were tested, and the results are given in the lower part of table 5. Again there was a strong preference in favor of the buds from which the hairs had been removed.

The results of these rather naive experiments suggest that it is the depth of the hairy covering on the flower buds of Strain #50 which discourages feeding, rather than some more subtle physiological condition associated with hairiness. The question remains: "Does hairiness serve as a simple mechanical barrier or does it evoke the 'wrong' tactile response in the visiting insect?" Preliminary experiments suggest that it is the simple mechanical feature which is important. When buds of Strain #50 are dipped quickly in hot paraffin wax and allowed to cool, a smooth surface is obtained under which the hairs are embedded. Buds treated in this way have approximately the same depth of barrier outside the calyx tissues as have untreated buds covered with hairs but the surface is rendered artifically glabrous. Weevils offered the choice of normal and waxed flower buds of Strain #50 showed no apparent preference (10 normal and 10 waxed buds received 23 and 21 punctures, respectively).

DISCUSSION.—By offering boll weevils a "choice" of flower buds of two cotton strains it has been possible to demonstrate preferences associated with three phases of the adult insects' activities (a) the location of the host plant, (b) the selection of feeding sites, and (c) location of sites for oviposition. The mechanisms underlying these preferences are apparently different for each phase, and an understanding of them should lead to a better knowledge of the sensory responses which govern the insect's reaction to the plant.

The strains tested differed in two major characters. Strain #50 had hairy buds with a normal complement of resin glands as contrasted with the glabrous and completely glandless condition of Strain #6. Because of the double contrast involved the individual effects of these characters on preference could not be tested directly, though to some extent their relative importance could be inferred.

Weevils were able to find flower buds of Strain #50 more readily than those of Strain #6. Since their ability to discriminate was unaffected by whether the tests were carried out under continuous illumination or in darkness, and since the presence or absence of the conspicuous bracteoles had no significant effect, it may be inferred that the "seeking response" has an olfactory basis. It seems highly probable that discrimination was determined by the presence or absence of the resin glands.

The ability of the insects to feed, as measured by the number of punctures, was similar on the two strains. However, when "choice" was provided a marked preference in favor of Strain #6 was exhibited. This preference was not rigidly determined—it became weaker as the total food available diminished (figures 1 and 2). Although a direct test was not possible with the strains available it seems likely that absence of hairs was the major factor determining preference. The fact that buds of Strain #50 from which the hairs had been removed artificially were preferred over controls supports this provisional assumption. Also it seems unlikely that the glands associated with the initial attraction (Experiment 1) should serve as a deterrent to feeding.

Table 5.—The effects on feeding preference of (A) removing the calyx and (B) removing the calyx hairs with acid, from flower buds of Strain #50.

	TOTAL PUNCTURES	"t"	P
		A	
Control	16		
Calyx removed	80	6.503	0.02–0.05
		B	
Control	25		
Acid treated	74	3.439	0.02–0.05

The failure of field experiments (Wessling 1958a) to demonstrate any effect of hairiness on feeding does not necessarily conflict with the above conclusion, because his experiments were conducted under conditions of heavy infestation. A weak preference would tend to disappear when food was in short supply (Experiment 3).

No significant difference was found in the ability of weevils to oviposit on the two strains, but again, when choice was provided, a marked preference was shown—this time in favor of Strain #50. The apparent switch from feeding on Strain #6 to oviposition on Strain #50 was investigated and it was concluded that lack of suitable egg-laying sites resulting from heavy feeding on Strain #6 was not entirely responsible. When relatively undamaged buds of both strains were compared, there was a marked preference in favor of Strain #50 (table 4).

These experiments provided no critical answer to the question whether the preferred oviposition on Strain #50 was due primarily to the presence of hairs or the presence of glands on this strain. But since 3 years' field experiments at this station have shown that hairiness discourages egg-laying, it seems unlikely that a reverse situation would be encountered in the laboratory. More likely the glands present in Strain #50 are important in stimulating oviposition, and if further experiments verify this possibility it is clear that the glandless condition would be a valuable asset to the plant breeder. One might expect that a glandless hairy combination would be strongly deterrent to oviposition.

REFERENCES CITED

Stanford, E. E., and A. Viehover. 1918. Chemistry and histology of the glands of the cotton plant, with notes on the occurrence of similar glands in related plants. Jour. Agric. Res. **13:** 419–35.

Stephens, S. G. 1957. Sources of resistance of cotton strains to the boll weevil and their possible utilization. Jour. Econ. Ent. **50**(4): 415–8.

Wannamaker, W. K. 1957. The effect of plant hairiness on cotton strains on boll weevil attack. Jour. Econ. Ent. **50**(4): 418–23.

Wessling, W. H. 1958a. Resistance to boll weevil in mixed populations of resistant and susceptible cotton plants. Jour. Econ. Ent. **51**(4): 502–6.

Wessling, W. H. 1958b. Genotypic reactions to boll weevil attack in Upland cotton. Jour. Econ. Ent. **51**(4): 508–12.

Some Effects of Guthion Alone and in Combination with DDT and of a Dieldrin-DDT Mixture on Growth and Fruiting of the Cotton Plant[1]

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ABSTRACT

Cotton plants were grown under insect-free conditions in the greenhouse and sprayed with Guthion at three rates, Guthion +DDT, and a dieldrin+DDT mixture. The plants sprayed with Guthion at 0.25 pound per acre produced more flowers than the untreated plants, whereas dieldrin+DDT retarded flower formation, boll set, and plant growth. All the insecticides reduced boll size.

The time required for bolls to mature was essentially the same for all treatments. The period for plant maturation was lengthened slightly by the lower rates of Guthion and resulted in the production of a few more bolls. The chlorinated hydrocarbons hastened maturity by having an opposite effect on plant growth. No adverse effect due to any of the treatments was found on the fibers.

Field experiments involving several insecticides applied as sprays for the control of cotton insects were conducted near College Station, Texas, in 1955 (Walker & Martin 1956). At the time of harvest, a considerable number of unopened bolls were observed in the plots that received applications of Guthion while cotton boll production and maturation in plots treated with chlorinated hydrocarbons were considered normal. The workers concluded that Guthion appeared to delay boll maturation. To investigate this hypothesis, we evaluated the response of cotton plants to applications of Guthion, dieldrin, and DDT under insect-free conditions in the greenhouse.

METHODS.—Seed of the Empire cotton variety were planted in 24 2-gallon, glazed earthenware jars filled with a mixture of equal parts of clay, pea gravel, and rotted cow manure. The seedlings were thinned to one per jar 2 weeks after emergence. When the plants started to square they were separated into six groups of four each and a weekly spray schedule was initiated with the insecticides listed in table 1. Applications were made by enclosing the plants within a 32-inch conventional spray tower and atomizing the desired insecticide into the tower. An accurate measure of fruiting activity was obtained by date-tagging the white blooms and dating the bolls at dehiscence. Spraying was discontinued after the ninth application of insecticide, at which time the first boll had opened. At the termination of the experiment, the seed cotton was collected and the dry weights of the above-ground portion of the plants were obtained. Selected seed and fiber properties were determined.

RESULTS.—*Vegetative Development and Boll Production.*—Treatment with 0.5 and 1 pound per acre of Guthion resulted in a reduction in plant dry weight when compared with the controls; however, treatment with 0.25 pound per acre was without effect (table 2). The addition of DDT to the 0.25-pound rate of Guthion caused a 22.4% reduction in dry weight while the dieldrin+DDT treatment reduced dry weight 26.7%.

Table 1.—Treatment rates and composition of insecticide sprays used on Empire cotton.[a]

TREATMENT		COMPOSITION OF CONCENTRATE (PER CENT)			CONCENTRATE PER LITER OF SPRAY MIXTURE (GM.)
Insecticide	Lb. per acre	Xylene	Triton X-100	Insecticide	
Untreated	—	—	—	—	—
Guthion	0.25	90.7	5.0	4.3	66.61
	0.5	85.3	5.0	9.6	71.08
	1.0	80.0	5.0	15.0	75.55
Guthion+DDT	0.25			3.1	
	2.0	66.8	5.0	25.1	90.53
Dieldrin+DDT	0.25			3.1	
	2.0	66.8	5.0	25.1	90.53

[a] Formulations were applied at the rate of 15 gallons per acre.

The Guthion+DDT and dieldrin+DDT formulations caused stunting of the plants by killing some of the meristematic regions of the stems. This was apparent when no lateral development resulted even though the terminals appeared to be dead; thus these plants remained in a dormant state after about the fifth application of the insecticides. Although reductions in dry weight occurred at the 0.5-pound and 1-pound per acre rates of Guthion, no killing of plant parts was apparent.

The plants receiving the 0.25- and 0.5-pound per acre rates of Guthion produced more flowers than the controls (table 2), whereas those sprayed with the dieldrin+DDT mixture produced 25% less. In addition, the dieldrin +DDT mixture reduced boll set by 20%.

The number of days required for the bolls to mature was determined. There were no significant differences between treatments (table 2).

Figure 1 shows the rate of flower production at 2-week intervals. The number of flowers formed during the first 2 weeks was relatively constant for all treatments. During the subsequent 4 weeks, it was apparent that the Guthion-treated plants produced more, while the dieldrin +DDT-treated plants produced fewer flowers than the untreated. This extension of flower production in the Guthion treatment would tend to delay plant maturity,

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[2] Crops Research Division and Entomology Research Division, respectively.
[3] In cooperation with the Texas Agricultural Experiment Station.

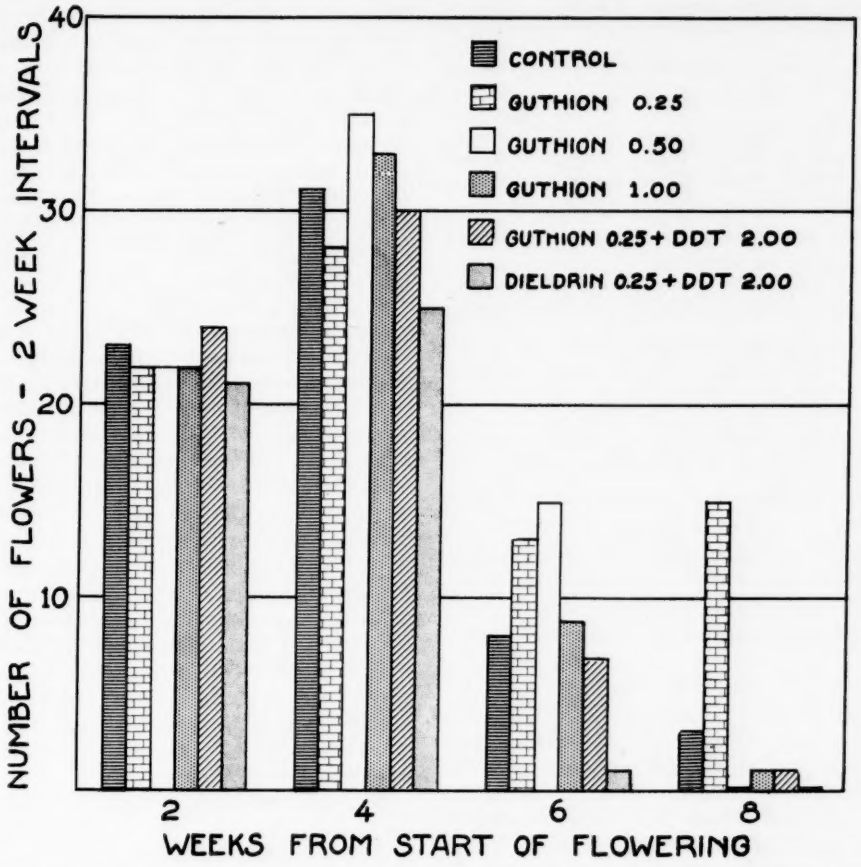

FIG. 1.—Flower production by Empire cotton as influenced by three rates of Guthion, Guthion+DDT and dieldrin+DDT.

while the production of fewer flowers, as resulted in the dieldrin+DDT treatment, would hasten maturity.

Yield of Seed Cotton and Boll Properties.—All plants that received the insecticide treatments produced less seed cotton than the controls (table 3). Although Guthion caused some reduction in yield, the addition of DDT to the lowest rate increased this effect. The greatest yield reduction occurred on plants receiving the dieldrin+DDT mixture. Also, all the insecticide mixtures caused smaller bolls to be produced, as measured by the weight of seed cotton per boll, than on the controls. Boll size on all treated plants, however, was relatively constant. It was noteworthy that the greatest reduction in seed index occurred in plants treated with the chlorinated hydrocarbons. The lint index of the Guthion-treated plants was higher than that of the control plants.

Table 2.—Effect of Guthion alone and in combination with DDT and of a dieldrin-DDT mixture on dry weight and flower and boll production of Empire cotton.[a]

Treatment		Dry Weight[b] (Gm.)	Number of		Per Cent Bolls Shed	Days for Boll Opening
Insecticide	Lb. per Acre		Flowers Produced	Bolls Set		
Untreated	—	78.8	16.0	6.3	60.6	51.6
Guthion	0.25	80.2	19.3	7.0	63.8	49.0
	0.5	70.6	17.8	7.3	59.0	49.5
	1.0	68.1	16.3	6.5	60.1	51.5
Guthion+DDT	0.25					
	2.0	61.2	15.5	6.3	59.4	51.2
Dieldrin+DDT	0.25					
	2.0	57.8	12.0	5.0	58.3	52.3
L.S.D. at 5% level		10.1	3.1	1.9	—	—
at 1% level		13.9	4.3	2.6	—	—

[a] All values as means per plant.
[b] Stems plus leaves.

Table 3.—Effect of Guthion alone and in combination with DDT and of a dieldrin-DDT mixture on yield of seed cotton, boll size, seed index and lint index of Empire cotton.[a]

Treatment		Grams of Seed			
Insecticide	Lb. per Acre	Cotton	Cotton per Boll	Seed Index[b]	Lint Index[c]
Untreated	—	38.9	6.3	14.3	6.22
Guthion	0.25	33.4	4.9	15.9	6.99
	0.5	36.2	5.0	14.3	6.57
	1.0	33.9	5.3	14.2	6.64
Guthion+DDT	0.25				
	2.0	28.4	4.7	13.5	6.06
Dieldrin+DDT	0.25				
	2.0	25.8	5.1	13.0	6.39
L.S.D. at 5% level		7.7	1.0		
at 1% level		10.6	1.4		

[a] All values as means per plant.
[b] Weight in grams of 100 seeds.
[c] Weight in grams of lint on 100 seeds.

Table 4.—Effect of Guthion alone and in combination with DDT and of a dieldrin-DDT mixture on fiber properties of Empire cotton.[a]

Treatment		Length (In.)			
Insecticide	Lb. per Acre	Upper Half Mean	Lower Half Mean	Tensil Strength[b]	Grams Fiber per Inch
Untreated	—	1.12	0.89	1.02	3.30
Guthion	0.25	1.12	0.93	1.08	3.65
	0.5	1.10	0.89	1.05	3.70
	1.0	1.12	0.91	1.03	3.27
Guthion+DDT	0.25				
	2.0	1.07	0.89	1.03	3.65
Dieldrin+DDT	0.25				
	2.0	1.10	0.90	1.02	3.56

[a] All values as means per plant.
[b] One thousand pounds per square inch.

Fiber Properties.—The insecticides had little effect on length or strength of fibers in this experiment (table 4). All plants except those treated with Guthion at the rate of 1 pound per acre produced coarser fibers than the untreated plants.

Discussion.—This investigation shows that under insect-free conditions in the greenhouse, the insecticides listed in table 1 caused plants to produce inferior bolls (smaller bolls and less total yield) as compared with untreated plants. Mistric & Martin (1956) compared the residual effectiveness of several insecticides, including toxaphene, Strobane, and Chlorthion, under field and laboratory conditions. With each of the insecticides, far greater boll weevil control was obtained on laboratory- than on field-treated plants, indicating that less of the insecticides was lost or degraded under greenhouse conditions. The plants in the current experiment were grown only in the greenhouse (to eliminate insects); however it would seem possible that field-grown plants may be less affected by the insecticides, because of insecticide loss due to wind drift and other environmental factors. On the other hand, any reduction in growth or yield of seed cotton of field-treated plants would normally be compensated by the insect protection afforded by the insecticides.

The plants treated with the two lower rates of Guthion tended to produce a greater number of flowers during the latter portion of the fruiting period (figure 1), even though boll shed was relatively constant. A trend toward increased boll production was also apparent (table 2). This may have been due to the stimulation in plant growth sometimes observed when phosphate insecticides are used (Hacskaylo & Ergle 1955). On the other hand, the cotton plant is unique in that a positive correlation exists between vegetative growth and fruit production. Eaton (1950) stated that in the absence of insects or other injury, the cotton plant retains most of the young bolls during its early fruiting period. As the boll load increases, a greater number are shed within a few days after anthesis. Also, small-bolled cotton varieties commonly mature more bolls, and shed fewer than large-bolled varieties. From Eaton's observations, it would seem possible for the Guthion-treated plants to support more but smaller bolls while the controls retained fewer but larger bolls, as was found in this investigation. Under the conditions herein described, the increased number of bolls would be of no practical significance since the total yield was less on the Guthion-treated plants than on the controls.

The dieldrin+DDT combination caused the greatest reduction in plant weight, flower production and boll set. Since this mixture limited growth by killing some of the terminal buds, the remaining vegetative portion supported a smaller number of bolls. Likewise, DDT added to Guthion definitely reduced dry weight and flowers set as compared with Guthion alone. It has been observed under field conditions that cotton plants treated with the chlorinated hydrocarbons seem to mature earlier than those treated with Guthion. The response of the former may be due solely to the retardation of plant growth as was observed in this investigation. Since stunted cotton stops fruiting earlier than normal cotton, the maturation time would be shortened.

Some of the reductions in plant growth and/or fruitfulness may have been caused by the solvent (xylene) in the spray formulations. This possibility seems remote, since dieldrin+DDT reduced dry weight by as much as 28%, as compared with the lowest rate of Guthion; however, both of these sprays contained the same concentration of xylene in the final spray mixture. This would strongly indicate that the plant responses herein reported were due to the insecticide employed.

References Cited

Eaton, F. M. 1950. Influence of growth "hormones" on boll retention by cotton plants. Bot. Gaz. **11**: 313–9.

Hacskaylo, Joseph, and D. R. Ergle. 1955. Effect of schradan on growth and photosynthetic pigments of the cotton plant. Bot. Gaz. **117**: 120–6.

Mistric, W. J., Jr., and D. F. Martin. 1956. Effect of sunlight and other factors on the toxicity of certain insecticides. Jour. Econ. Ent. **49**(6): 757–60.

Walker, J. K., Jr., and D. F. Martin. 1956. Comparison of certain insecticides for boll weevil and bollworm control. Paper presented at the Annual Meeting of the Southwestern Branch, Entomological Society of America.

Respiration Rates of Larvae of Drone and Worker Honey Bees, *Apis mellifera* L.[1]

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Abstract

The oxygen consumptions of drone and worker honey bee larvae were determined at 32° C. over the period between hatching and the sealing of the cells prior to pupation. A decrease in respiration rates with increasing age was found in both drone and worker larvae when the rates were calculated on a unit weight basis, but in both castes the oxygen consumption *per larva* rose rapidly in the period following hatching, subsequently increasing less rapidly. Drone larvae consumed greater amounts of oxygen than worker larvae of the same weight, and this was apparently linked with their more rapid increase in weight.

The respiration rates of larvae of the queen and worker honey bee have been measured at various stages of development by Melampy & Willis (1939), but no comparable work appears to have been carried out on drone larvae. In consequence, it was felt desirable to study their oxygen uptake from hatching to pupation, and thus complete the picture for the larvae of all three castes. For comparison worker larvae of various ages were also studied.

Melampy & Willis (1939) used a temperature of 35° C. in their experiments but in the present instance 32° C. was chosen because it was originally hoped to be able to make a direct comparison between larval and adult rates (Allen 1958) at this temperature.

Methods.—The oxygen uptake of both drone and worker larvae was measured in Warburg constant volume respirometers (22 to 29 ml. capacity) over periods of 1 hour at a temperature of 32° C. Carbon dioxide produced during the experiment was absorbed by 0.2 ml. 5% KOH solution in the centre wells of the flasks. Prior to the experiments the larvae were lifted carefully from the cells of the brood combs and any adhering brood food was removed with filter paper before they were placed in the flasks in a dilute honey solution containing 30% sugars (measured in a refractometer at 18.5° C.). The volume of honey solution was normally 0.2 ml. but in a few of the earlier experiments 0.3 ml. was used. In all cases, however, the liquid formed only a very shallow layer over the floor of the flasks, serving to keep the larvae moist and in a nutritive medium without covering them.

The larvae were weighed at the end of the experiments, rather than at the beginning as is perhaps more customary, in order to reduce to a minimum the amount of handling which they received prior to the experiments. Before weighing, the surfaces of the larvae were carefully dried with filter paper.

Owing to the great difference in size between newly-hatched and fully grown larvae it was found necessary to vary the number per flask because the oxygen consumption of one newly-hatched larva would not have been great enough for accurate measurement, while oxygen shortage would rapidly have occurred if several of the largest larvae had been put into one flask. The selection of

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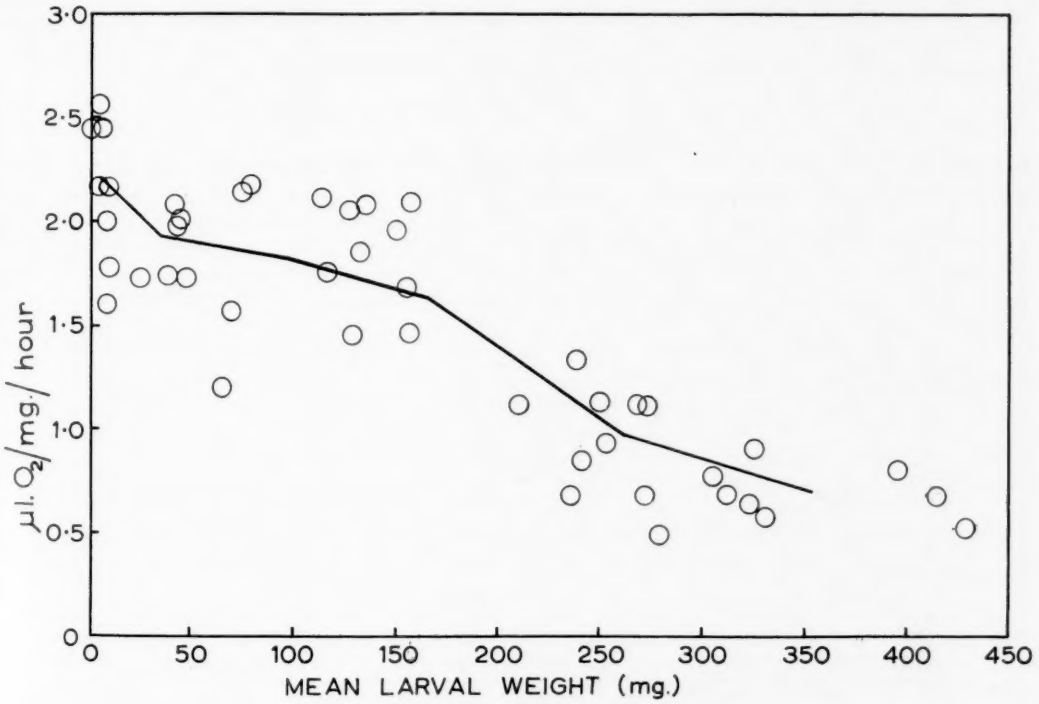

Fig. 1.—Drone larvae: rate of oxygen uptake per unit weight.

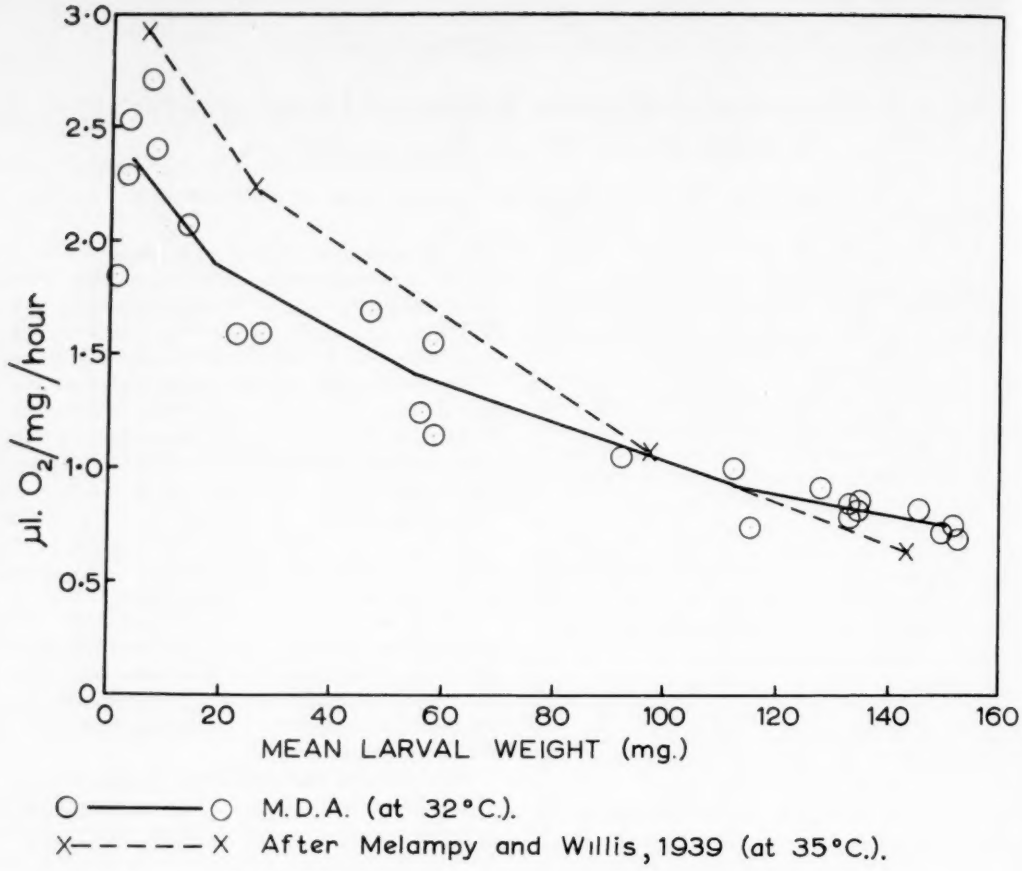

FIG. 2.—Worker larvae: rate of oxygen uptake per unit weight.

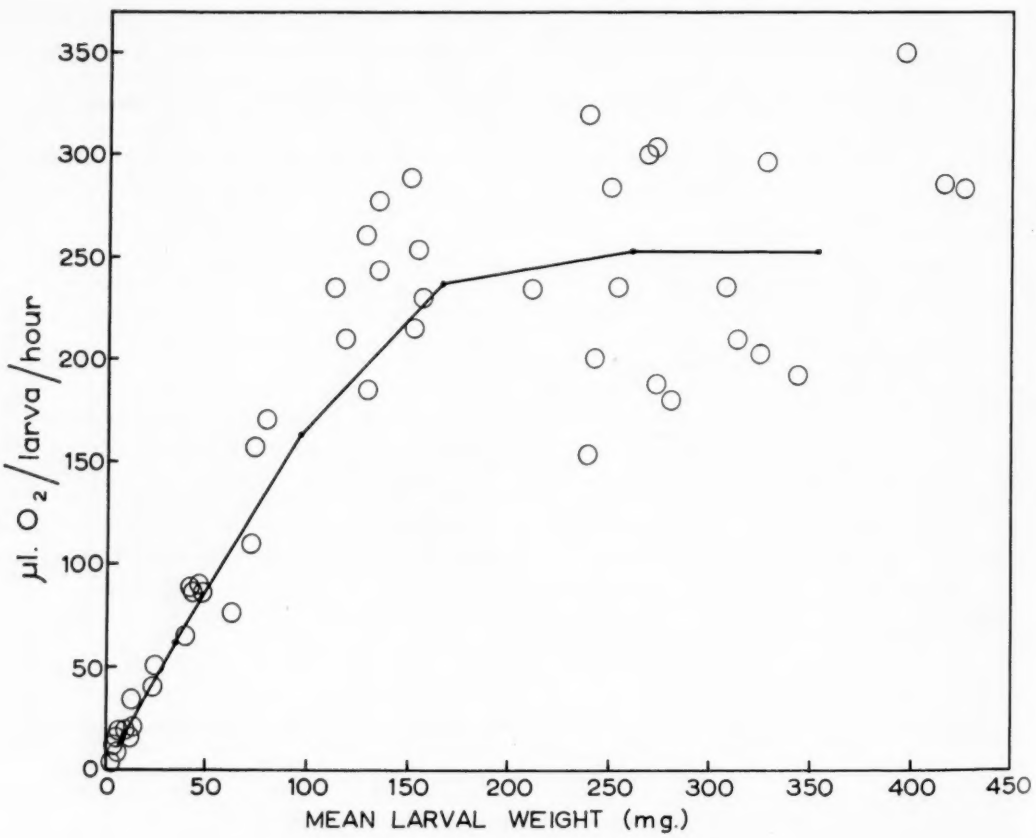

FIG. 3.—Drone larvae: rate of oxygen uptake per larva.

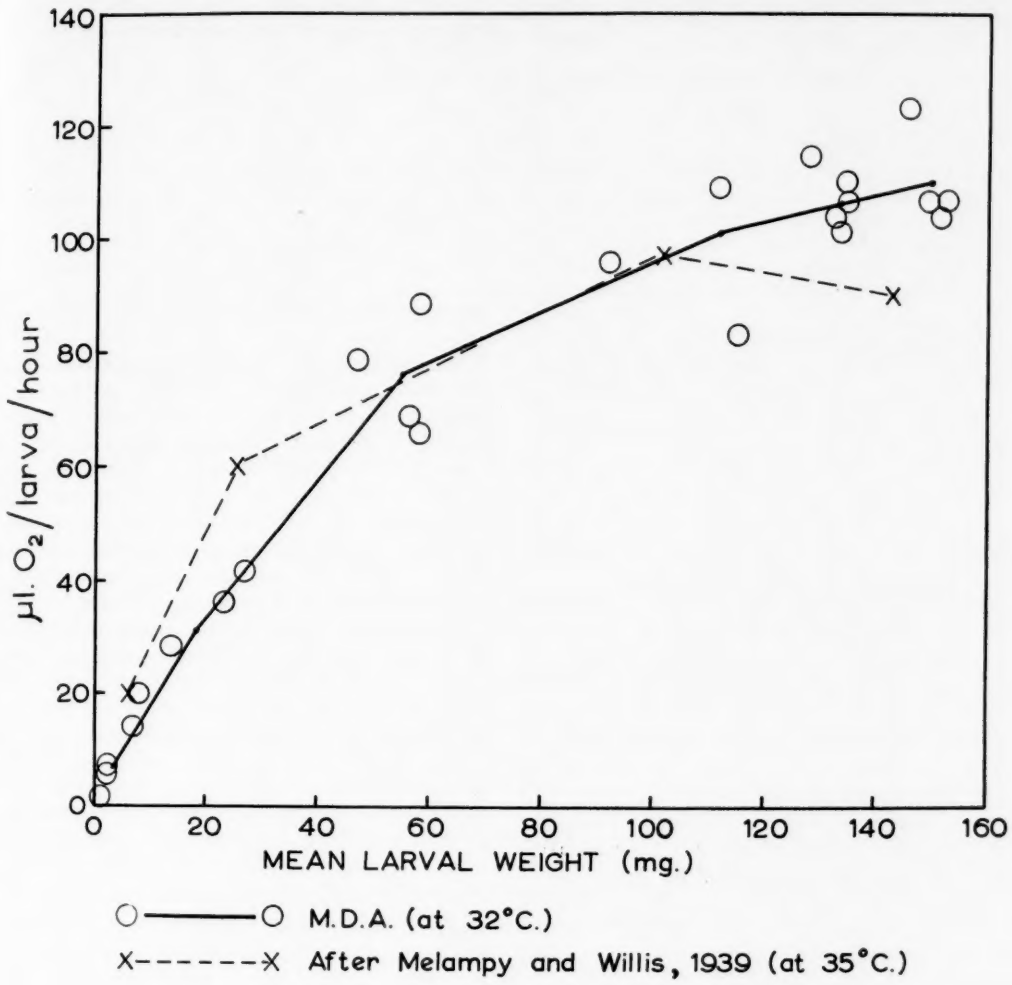

FIG. 4.—Worker larvae: rate of oxygen uptake per larva.

a group of larvae of approximately identical size for inclusion in the same flask was based on a visual assessment, assisted by the fact that a number of cells in one comb usually contained larvae of very similar age. In order to compensate for variations in the volume of tissue per flask a correction was introduced into the calculation of the flask constants (see Umbreit *et al.* 1951), and for this purpose it was considered sufficiently accurate to assume that the larvae had a specific gravity of 1.

RESULTS.—In figure 1 are shown the rates of oxygen uptake ($\mu l.O_2$/mg. live wt./hour) of drone larvae of various ages from hatching to the time immediately preceding the sealing of the cell (approx. 6 days after hatching). Each point represents the mean value obtained for the larvae in one respirometer, while the line drawn through the points joins the mean values of groups of eight consecutive points. It is clearly illustrated that the oxygen consumption of young drone larvae is considerably more rapid per unit weight than that of the older larvae, there being a steady decrease in respiration rate with increasing larval weight.

Figure 2 shows the rate of respiration of worker larvae over the same period and on the same basis as for the drone larvae. The line drawn through the points in this graph connects the means of groups of four consecutive points. Rather smaller variability is apparent here than in figure 1 and this is possibly associated with the lower maximum weights and slightly shorter larval period of workers as compared with drones, but the overall picture is very similar to that already discussed.

If the oxygen consumptions per larva instead of per unit weight are plotted, it is found that in both drones and workers there is an increase in consumption with increasing weight, but that this increase becomes progressively smaller as the larvae become older (figs. 3 and 4). The means in figures 3 and 4 are calculated in the same manner as in figures 1 and 2.

DISCUSSION.—Drones have a longer larval period than workers, but in the 6 days which elapse between the hatching of the eggs and the sealing of the larval cells they reach a weight of approximately 400 mg., whereas the worker larvae during the corresponding period (lasting approximately 5 days) only reach an approximate weight of 140 mg. This difference in the rate of growth is clearly shown in figure 5 where the logarithms of the larval weights (from Straus 1911 and from Melampy &

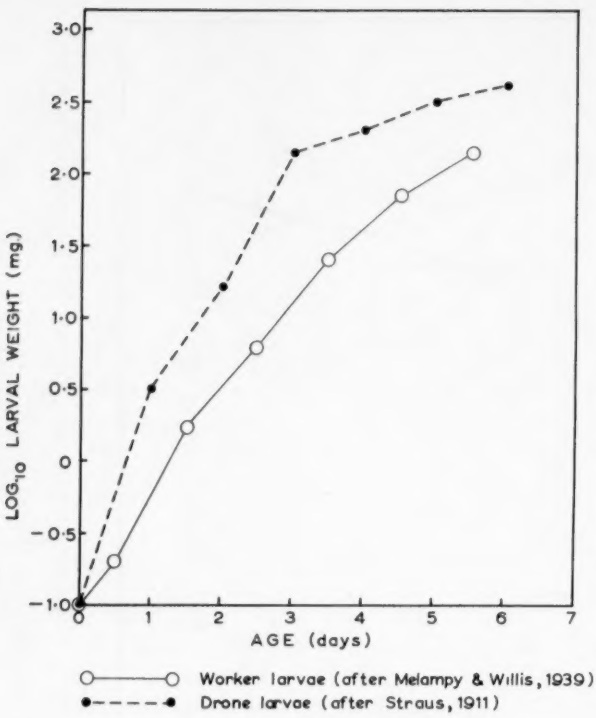

FIG. 5.—Relative growth rates of worker and drone larvae.

Willis 1939) are plotted against time, the slope of this curve giving a picture of the rate of increase in weight relative to the actual weight at any one time (relative growth rate). At any particular weight the drone larvae therefore have a higher relative growth rate than worker larvae of the same weight, and it is only when the drones have exceeded the maximum weight of the workers that their relative growth rate decreases.

In view of this higher relative growth rate of the drone larvae one would expect them to have a higher respiration rate than the worker larvae of the same weight, and this is borne out by comparison of the mean values in figures 1, 2, 3 and 4. For the sake of clarity the mean rates of oxygen consumption at arbitrarily selected larval weights have been extracted from these figures and are given in table 1.

Table 1.—Respiration rates of worker and drone larvae.

Larval Weight (Mg.)	O_2 Uptake (μl. per Mg. per Hour)		O_2 Uptake (μl. per Larva per Hour)	
	Worker	*Drone*	*Worker*	*Drone*
20	1.9	2.1	34	35
40	1.6	1.9	58	70
60	1.4	1.9	78	104
80	1.2	1.9	87	136
100	1.0	1.8	96	167
120	0.9	1.8	102	188
140	0.8	1.7	107	209

The rates of oxygen uptake (both on a unit weight and on a whole larva basis) of the two groups become progressively more diverse as the larval weights increase, until at 140 mg. the drones are using approximately double the amount of oxygen as compared with the workers.

Thus both drone and worker larvae show decreases in respiration rate with increasing weight, but the oxygen consumption of the drone larvae is relatively greater than that of worker larvae of the same weight presumably on account of a higher relative growth rate.

No previous figures for the respiration rates of drone larvae appear to be available for comparison with those presented in figures 1 and 3; the values for worker larvae found by Melampy & Willis (1939) are, however, shown in figures 2 and 4. Although their experiments were carried out at 35° and not at 32° C. as in the present case, the two sets of results exhibit a fair degree of correspondence, and it may be that in the region of the optimum temperature the rate of oxygen consumption remains fairly stable.

REFERENCES CITED

Allen, M. Delia. 1958. A study of some activities of the honeybee. Univ. of London: Ph.D. thesis.

Melampy, R. M., and E. R. Willis. 1939. Respiratory metabolism during larval and pupal development of the female honeybee. Physiol. Zool. **12:** 302–11.

Straus, J. 1911. Die chemische Zusammensetzung der Arbeitsbienen und Drohnen während verschiedenen Entwicklungsstadien. Zeitschr. Biol. **56:** 347–97.

Umbreit, W. W., R. H. Burris, and J. F. Stauffer. 1951. Manometric techniques and tissue metabolism. Burgess Publishing Co., Minneapolis.

NOTICE TO MEMBERS

Authors are urged to consult the latest revised list of "Common Names of Insecticides." See JOURNAL OF ECONOMIC ENTOMOLOGY 52(2): 361–362. April 1959.

The chemical definition of each insecticide, the name of which does not appear in this list, should be given the first time the name occurs in a manuscript accepted for publication by the Entomological Society of America; also in the abstract.

Joint Action of DDT and Other Chlorinated Hydrocarbon Insecticides against Resistant Boll Weevils[1]

J. S. Roussel,[2] M. S. Blum[2] and N. W. Earle[3]

Abstract

The joint action of DDT in combination with toxaphene, endrin or lindane against boll weevils (*Anthonomus grandis* Boh.) differing in susceptibility to the individual insecticides was studied in the laboratory. Weevils were treated topically, or exposed to a residual film for mortality studies. These were either laboratory reared or field collected. Penetration and metabolism of DDT was studied when applied alone or in mixtures with other insecticides.

Mixtures of insecticides exhibited additive effects only for boll weevils susceptible to chlorinated hydrocarbon insecticides. However, when weevils resistant to these insecticides were used, the mixture of toxaphene-DDT exhibited synergistic effects. Mixtures of endrin-DDT and lindane-DDT exhibited additive effects only.

Penetration of DDT appeared to be equal for both strains. Separate applications of toxaphene and DDT to different sites of the weevil were as effective as a single application of the mixture. DDT applied as late as 96 hours subsequent to an application of toxaphene resulted in high mortality of the weevils. However, repeated applications of toxaphene failed to give much of an increase in mortality.

Weevils did not metabolize DDT as rapidly when treated with the mixture as when treated with DDT alone. The metabolism of toxaphene is unknown.

Although the toxaphene-DDT mixture exhibits synergistic activity against resistant boll weevils, the combination was not as effective against resistant boll weevils as toxaphene alone against susceptible boll weevils.

Highly successful control of the boll weevil, *Anthonomus grandis* Boh., was obtained with chlorinated hydrocarbon insecticides for the period 1947 through 1954. However, by 1955 resistance to these insecticides had developed to the extent that the boll weevil could no longer be controlled satisfactorily with them (Roussel & Clower 1955). In the areas involved cotton growers readily changed from those insecticides previously used to the organophosphorous insecticides and calcium arsenate. The use of certain mixtures of chlorinated hydrocarbon insecticides in field plots indicated that some degree of control of resistant boll weevils was obtained when compared with that obtained with the individual insecticides. In general, whenever mixtures of insecticides were used on cotton, DDT was one of the chemicals included.

In view of the increased effectiveness demonstrated in field plots by these mixtures, it was found desirable to undertake more detailed laboratory studies of the action of DDT in combination with other chlorinated hydrocarbon insecticides.

Experimental Methods.—Boll weevils used in the course of these studies were either field collected as adults or reared from infested squares which had been collected in the fields. Chlorinated hydrocarbon resistant boll weevils were collected in five different localities; Batchelor, Lettsworth, Tallulah and St. Joseph, Louisiana, and Greenville, Mississippi. Susceptible weevils were collected from a cotton field in Baton Rouge, Louisiana. All weevils were fed fresh squares in the laboratory daily until used in the experiments.

Dosage mortality data were obtained by one of the following two methods:

Topical Application.—Weighed boll weevils were treated by placing a one-μl drop of an acetone solution of the desired chemical on the dorsal surface of the metathoracic segment of individual weevils. The insecticide was administered by a calibrated syringe, the plunger of which was driven by a micrometer. After treatment, groups of five weevils were placed in half-pint jelly jars covered with perforated lids and were provided with cotton squares. A minimum of six replications were made for each dose.

Exposure to a Residual Deposit.—Two milliliters of an acetone solution of the desired chemical were placed in 100×15 mm. petri dishes and the solvent was evaporated by means of a stream of air directed over the dishes. Ten weevils were placed in each petri dish which was then covered with a galvanized screen lid. The dishes were stored inverted with the screen downward in a constant temperature room at 27° C. and 60% relative humidity. The weevils, being attracted to light, remained in constant contact with the film of chemical until an effective dose of the toxicant was absorbed. Thereafter, the weevil no longer was able to coordinate its movements and dropped to the screen cover. Fresh cotton squares were provided daily. Mortality counts were made after 48 hours. Dosage-mortality curves were obtained by plotting mortality on log probability paper. LD_{50} values were computed by slope determination of the response curve.

Penetration and metabolism studies were performed on groups of 15 weevils. Four replicates were employed for each time interval. After treatment with the insecticides, the weevils were placed in 125-ml. Erlenmeyer flasks without food and stored at about 27° C. After the appropriate time intervals, the weevils were given three successive 15-ml. rinses with distilled ethyl ether. The rinsed weevils were mascarated in a mortar with about 10 grams of anhydrous sodium sulphate and the resulting powder was transferred to a 4-ounce bottle. The mortar and pestle were washed with 5 ml. ether, the washings being added to the ground weevils. Fifteen additional mls. of ether were added to the brei after which it was extracted for one-half hour on a mechanical shaker. The extract was filtered into a 125-ml. Erlenmeyer flask and the ground weevils were extracted again. After the second extraction, the ground weevils were poured into a funnel and were washed with an additional 15 ml. of ether. After evaporation of the ether on a steam bath, the samples were either analyzed directly, or if large amounts of fat

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[2] Louisiana Agricultural Experiment Station.

[3] Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture.

Table 1.—LD_{50}'s, expressed as mg./gm., of boll weevils treated topically on the metathoracic segment with a microdrop of insecticide.

INSECTICIDE	SUSCEPTIBLE STRAIN	RESISTANT STRAIN
Toxaphene	0.240	6.80[a] >5.30
Toxaphene+DDT (2-1)	0.240+0.120	0.500 +0.250
DDT	3.000[a]>1.667	2.400[a]>1.40
Endrin	0.019	0.060
Endrin+DDT		0.040 +0.400
Lindane	0.016	0.150[a]>0.140
Lindane+DDT (1-10)		0.078 +0.780
Lindane+DDT (1-2.5)	0.015+0.037	
Guthion	0.0018	0.0012

[a] Obtained by extrapolation.

were present a chromatographic cleanup was employed as follows. To a 1-inch diameter chromatographic column containing a fritted disc were added 3 grams of anhydrous sodium sulphate, 10 grams of alumina[4] and 3 grams of sodium sulphate in this order. The weevil extract dissolved in 10 ml. of petroleum ether (b.p. app. 65° C.) was added to the column previously wet with solvent. The column was then washed continuously with petroleum ether and the first 75-ml. portion of eluate was collected for analysis. This method has been shown to remove quantitatively both DDT and DDE from the column whereas the interfering material remains absorbed.

The following chemicals were used in this study:

p,p′ DDT: 2, 2-bis-(p-chlorophenyl)-1,1,1-trichloroethane, recrystallized twice from ethanol: m.p. 108–109° C.

p,p′ DDE: 2, 2-bis-(p-chlorophenyl)-1,1-dichloroethylene, obtained by dehydrochlorination of DDT in alcoholic KOH and recrystallized twice from ethanol; m.p. 88–89° C.

Toxaphene (Technical) 67–69% chlorine. ESA Standard from Nutritional Biochemicals Corporation.

Lindane: Gamma-1,2,3,4,5,6-Hexachlorocyclohexane. ESA Standard from NBC.

Endrin (Technical) 95% 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-endo-endo-dimethanonaphthalene.

Guthion: (Technical) 97% *O,O*-dimethyl *S*-(4-oxo-benzotriazino-3-methyl) phosphorodithioate.

DDT and DDE were analyzed by the method of Schechter *et al.* (1945). DDT-DDE mixtures were determined by the procedure of Mattson *et al.* (1953).

RESULTS.—Dosage-mortality data for several insecticides alone and in combination with DDT are given in table 1. The use of DDT in a mixture with one of the other chlorinated hydrocarbon insecticides did not appreciably affect the dosage required for an LD_{50} of susceptible weevils when determined on the basis of the other chemical alone. However, when the dosage mortality curves were examined a slight increase in slope of the curves was observed for the combinations. For example, figure 1 depicts the curves for toxaphene, DDT and a mixture of toxaphene-DDT. The toxaphene and DDT curves are diverging with toxaphene having a considerably steeper slope than DDT. A still greater steepness of slope is obtained with the mixture of toxaphene-DDT. When computation is made to test similar action (Wadley 1945) it seems that the test overestimated the dosage

[4] Alumina, activated, chromatographic, powdered, catalyst grade, AL-0109P (90% A1203). Harshaw Chemical Co., Cleveland, Ohio.

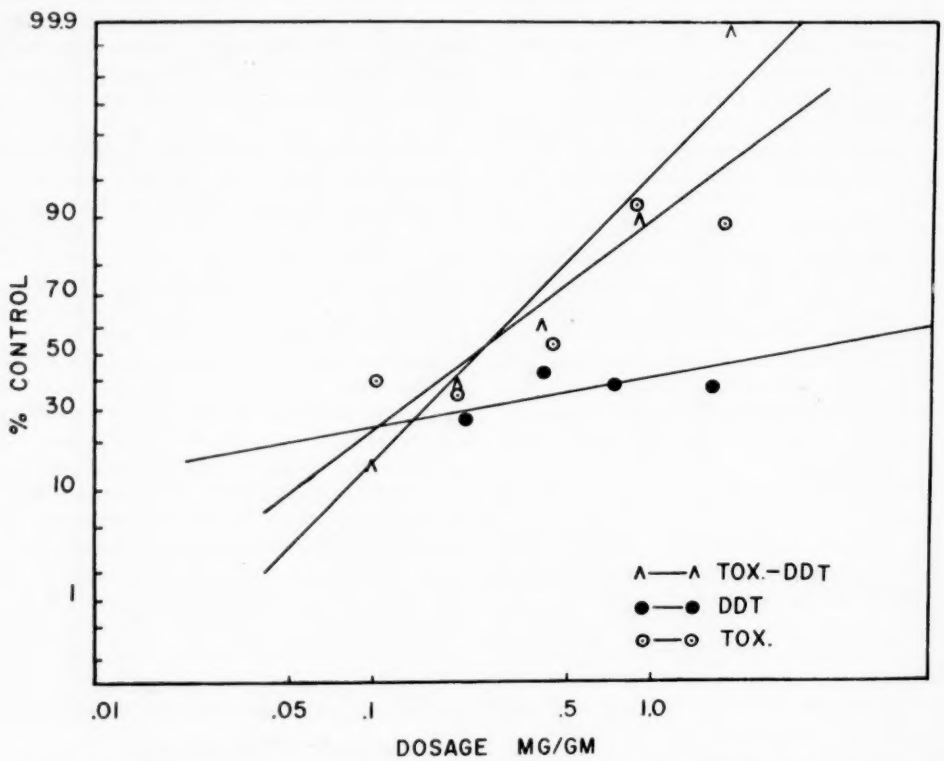

FIG. 1.—Probit-log dosage lines for toxaphene, DDT and a mixture of toxaphene-DDT on susceptible weevils.

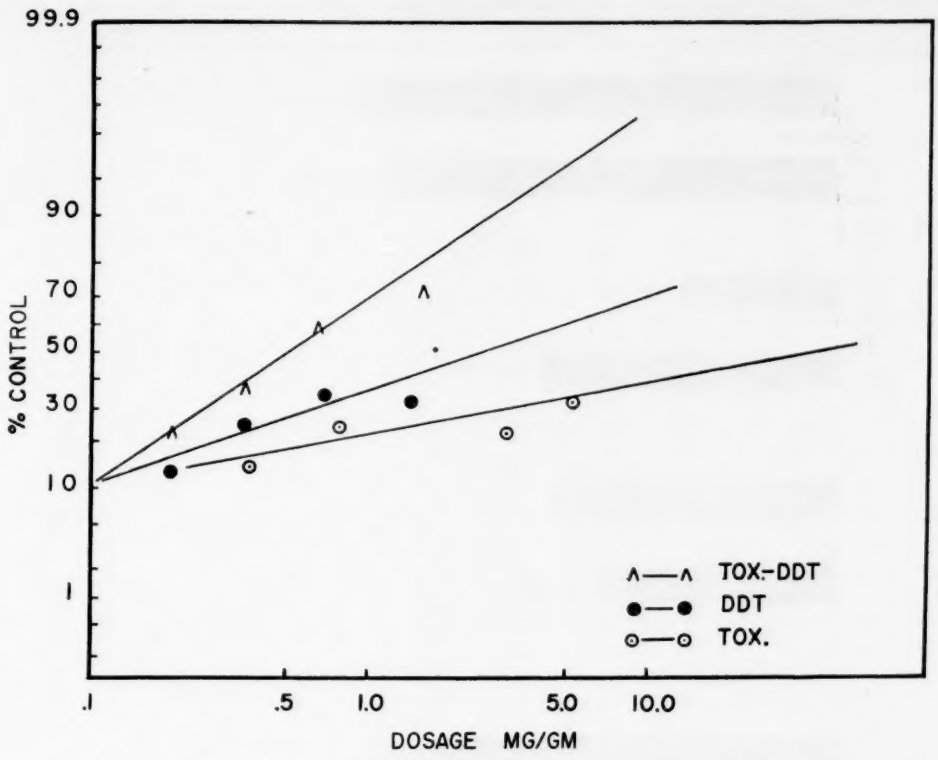

FIG. 2.—Probit-log dosage lines for toxaphene, DDT and a mixture of toxaphene-DDT on resistant weevils.

acting in the lower concentrations and underestimated the dosage acting in the higher concentrations.

Slightly diverging dosage-mortality curves were obtained for toxaphene and for DDT on resistant boll weevils. A much steeper slope resulted from use of the mixture on this strain of weevils (fig. 2). In fact, when computation was made to test similar action, evidence of greater mortality than expected was found for the mixture of toxaphene-DDT.

Both the susceptible and resistant strains responded essentially alike to DDT. When DDT was converted to "toxaphene equivalent," each unit of DDT was equal to 0.08 of a unit of toxaphene for the susceptible strain, but for the resistant strain a unit of DDT was equal to 2.83 units of toxaphene.

Actual mortalities for mixtures of endrin-DDT and lindane-DDT were but slightly greater than expected for the two materials, thus showing similar action.

Since the toxaphene-DDT mixture was so much more effective than either of the chemicals alone for control of resistant boll weevils, it was thought that the combination might promote the entrance of either one or both chemicals into the insect body. To evaluate this possibility, the insecticides were placed separately on different sites of the individual insect. Initially, the mixture was applied to either the thorax or the ventral surface of the abdomen to study the effect of site of application on response to the mixture. As shown in figure 3, mortality was almost the same regardless of whether the insecticide mixture was placed on the dorsal surface of the thorax or on the ventral surface of the abdomen. A similar test was made for DDT; a slightly lower mortality resulted when the material was applied to the abdomen. When toxaphene was applied on the dorsal surface of the thorax and DDT on the ventral surface of the abdomen of the individual weevil, the activity expected of the mixture was still evident (fig. 3).

The results of a second application of the insecticide or mixtures of insecticides to survivors are given in figure 4. Resistant boll weevils were treated with one of the chemicals indicated. Forty-eight hours after the initial treatment a repeat application was given to survivors. For all insecticides some increased mortality resulted; however, mortality, varied from none in the low dosage of endrin to a high mortality for the toxaphene-DDT mixture (fig. 4). The greatest response from the repeated application of the insecticides was obtained for the toxaphene-DDT mixture. The response ranged from a mortality of 30% 48 hours after the initial application to 70% 120 hours after the second treatment for a dosage of toxaphene-DDT (5 and 2.5 μg. per weevil) to an increased mortality from 40 to 100% for the high dosage of toxaphene-DDT (fig. 4).

A second series of repeat application of insecticide was made. In this study groups of 200 weevils were treated topically with toxaphene-DDT mixture, toxaphene, and DDT. Ninety-six hours after the initial treatment survivors of each treatment were removed from the holding cage and randomly separated into two groups. At this time one group was treated with toxaphene and the second with DDT. So few weevils survived the toxaphene-DDT mixture after 96 hours that an insufficient number of weevils remained for a second treatment. Four groups of weevils remained for the second treatment. Two groups

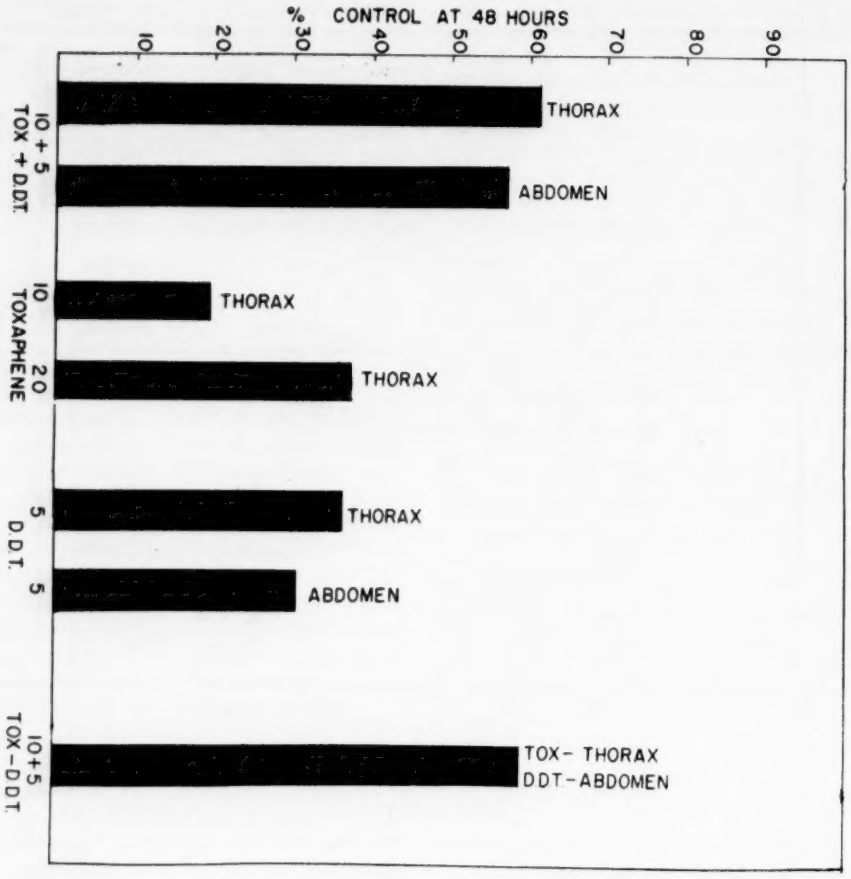

FIG. 3.—Mortality of resistant boll weevils from insecticide applications to different sites.

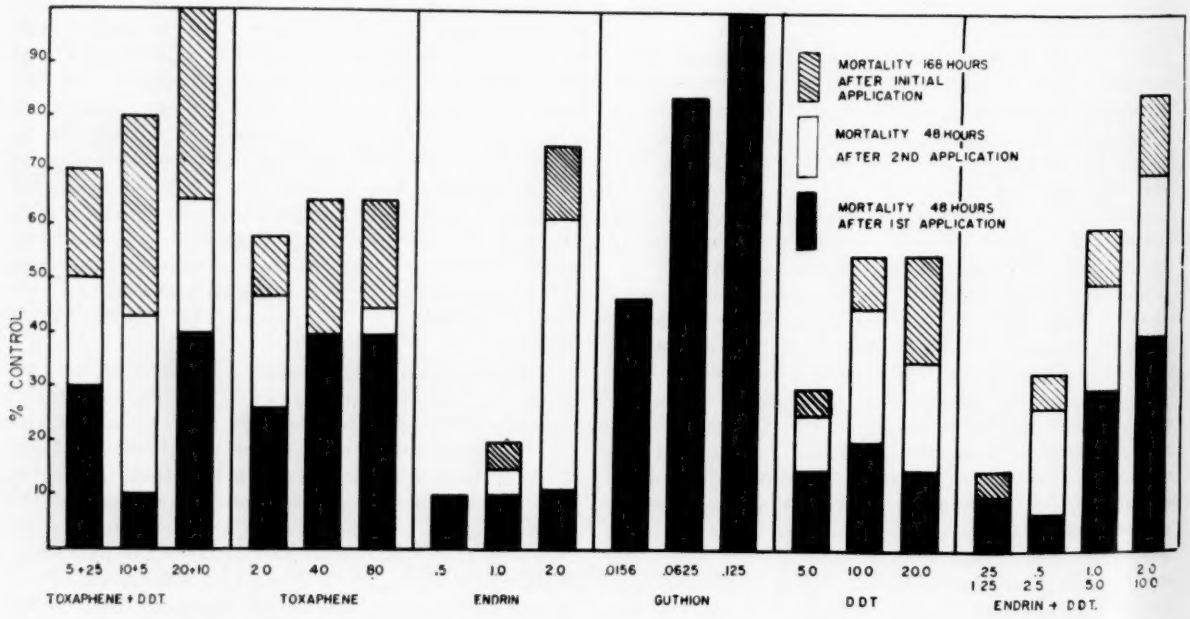

FIG. 4.—Mortality of resistant boll weevils where survivors received repeat application of insecticide 48 hours after initial treatment.

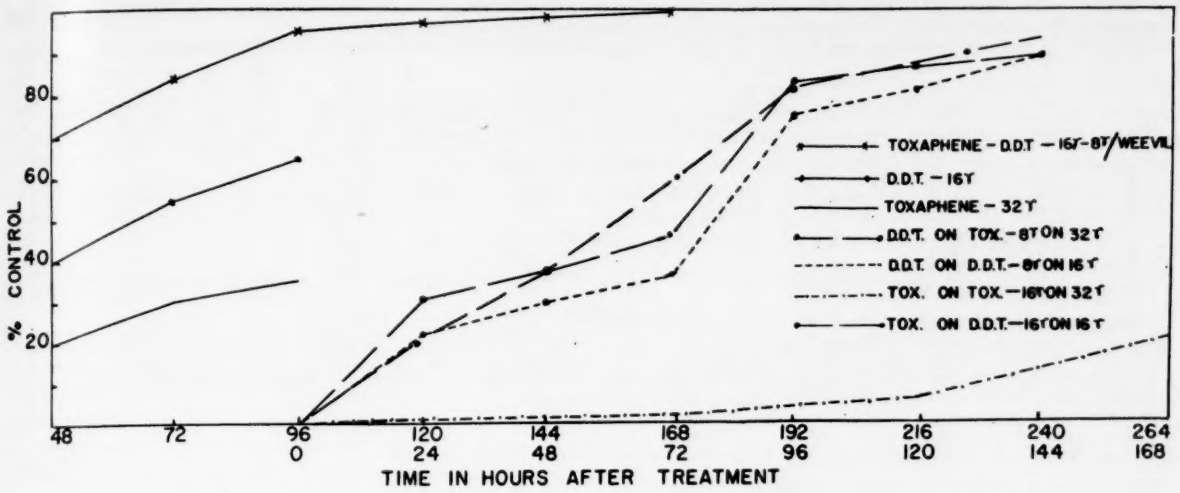
% CONTROL
80
60
40
20
TOXAPHENE - D.D.T. - 16T-8T/WEEVIL
D.D.T. - 16T
TOXAPHENE - 32T
D.D.T. ON TOX. - 8T ON 32T
D.D.T. ON D.D.T. - 8T ON 16T
TOX. ON TOX. - 16T ON 32T
TOX. ON D.D.T. - 16T ON 16T
48 72 96 120 144 168 192 216 240 264
0 24 48 72 96 120 144 168
TIME IN HOURS AFTER TREATMENT

FIG. 5.—Mortality of resistant boll weevils receiving combinations of split treatments of toxaphene and DDT. Second treatment on survivors 96 hours after initial treatment.

received toxaphene initially; 96 hours later one of these groups was treated again with toxaphene and the other with DDT. The remaining two groups were treated with DDT initially; 96 hours later one of these groups was treated with toxaphene and the second with DDT. Results of this study are shown in figure 5. In all treatments where DDT was involved, either in the first application or the second, mortality was high; however, where toxaphene followed toxaphene, mortality among the weevils remained low (fig. 5).

Exposure to Residual Deposits.—Results of exposure of resistant boll weevils to residual deposits of insecticides alone and in mixtures are given in table 2. In general, increased activity was noted for all mixtures over that for each insecticide alone. Again the greatest increase in activity was from the toxaphene-DDT mixture. Response from toxaphene alone was negligible, even with dosages as great as 80 mg. per petri dish. Dosages of toxaphene-DDT mixtures of 5.0 and 2.5 mg. per dish gave high mortality.

Chemical Analysis.—Results of analyses to determine internal DDT and its metabolite DDE following topical application of DDT, toxaphene-DDT, (each applied separately to different sites of the boll weevil) and endrin-DDT are presented in tables 3 and 4. Internal DDT present in weevils at 7 and 24 hours after application was considerably greater for the mixtures than for DDT applied alone. In fact, this ranged from 29% more internal DDT for the endrin-DDT mixture to 81% more internal DDT for the toxaphene-DDT mixture after 7 hours. After 48 hours the range was from 27% to 63% greater for the respective mixtures.

The amount of DDE present in boll weevils after 24 hours was greatest for DDT applied alone and smallest for the mixture of toxaphene-DDT (tables 3 and 4).

DISCUSSION.—Insecticide combinations have been used often for control of insect and mite pests of cotton. They have been especially useful in pest complexes where one insecticide was highly effective against a particular pest species but relatively ineffective against a second species. An excellent example of such a combination is the 3-5-40 mixture (3% gamma isomer of BHC-5% DDT-40%

Table 2.—Mortality of boll weevils by the petri-dish residual film method of treatment.

INSECTICIDE	DOSAGE MG./DISH	PER CENT CONTROL[a]			
		Batchelor		Greenville	
		48 Hrs.	72 Hrs.	48 Hrs.	72 Hrs.
Lindane	0.25	0	0	25	71
	0.5	46	58	38	36
	1.0	81	92	56	79
	2.0	88	100		
Lindane+DDT (1–10)	0.25 + 2.5	90	92		
	0.5 + 5.0	95	100		
	1.0 +10.0	89	100		
Lindane+DDT (1–5)	0.125+ 0.63			13	21
	0.25 + 1.25			50	71
	0.5 + 2.5			25	71
	1.0 + 5.0			25	86
Endrin	0.125			0	29
	0.25	61	58		
	0.5	50	50	19	36
	1.0	60	92	25	50
	2.0	50	83	44	57
Endrin+DDT (1-10)	0.25 + 2.5	69	92		
	0.5 + 5.0	81	92		
	1.0 +10.0	76	100		
Endrin+DDT (1–5)	0.125+ 0.63			37	71
	0.25 + 1.25			56	86
	0.5 + 2.5			18	64
	1.0 + 5.0			50	86
Toxaphene	20.0	10	26	0	0
	40.0	5	11	0	0
	80.0	11	17	0	7
Toxaphene+DDT (2–1)	5.0 + 2.5			63	86
	10.0 + 5.0	65	100	50	100
	20.0 +10.0	85	100	100	100
DDT	5.0	52	100	19	50
	10.0	13	77	0	0
	20.0	30	77	13	40

[a] Weevils collected at Batchelor, La., or Greenville, Miss.

Table 3.—DDT and DDT metabolites recovered from field collected chlorinated hydrocarbon-resistant boll weevils treated topically with a toxaphene-DDT mixture, with DDT, or with an endrin-DDT mixture.[a]

Hours	μg. DDT External	Per Cent DDT External	μg. DDT Internal	Per Cent DDT Internal	μg. DDE Internal	Per Cent DDE Internal	μg. Internal DDT Metabolized	Per Cent Internal DDT Metabolized	Per Cent Internal DDT Metabolized to DDE	μg. Recovered DDT & DDE	Per Cent Recovered DDT & DDE
					Toxaphene—DDT mixture[b]						
0	4.91	98.3								4.91	98.3
7	3.06	61.3	0.56	11.2	0	0	1.38	71.2	0	3.62	72.4
24	2.68	53.6	0.78	15.6	0.07	1.39	1.54	66.4	3.02	3.49	69.8
					DDT[c]						
0	4.94	98.8								4.94	98.8
7	3.21	64.3	0.31	6.22	0.02	0.4	1.48	82.8	1.12	3.54	70.8
24	2.79	55.8	0.48	9.61	0.14	2.81	1.73	78.4	6.34	3.41	68.3
					Endrin—DDT mixture[d]						
0	4.94	98.8								4.94	98.8
7	3.18	63.7	0.40	8.1	Trace	Trace	1.42	78.1	Trace	3.58	71.6
24	2.70	54.1	0.61	12.2	0.11	2.1	1.69	73.4	4.71	3.42	68.4

[a] Sixty weevils analysed per time interval. Results are expressed on a per weevil basis.
[b] 48-hour mortality = 62 ± 8%.
[c] 48-hour mortality = 14 ± 6%.
[d] 48 hour mortality = 41 ± 11%.

sulphur) used extensively on cotton. Investigation of the joint action of these combinations has received only limited attention. Studies in this laboratory with boll weevils susceptible to the chlorinated hydrocarbon insecticides showed additive effects only with combination of toxaphene-DDT, lindane-DDT and endrin-DDT. Gaines *et al.* (1951) concluded that the joint action of the toxaphene-DDT mixture was merely additive and exhibited no synergistic action. Similar results were obtained by March *et al.* (1952) with susceptible house flies.

However, when boll weevils resistant to the chlorinated hydrocarbon insecticides were used, results obtained with the toxaphene-DDT mixture were greater than can be expected from the mere additive effects of two insecticides of similar action. Wadley (1945) defined synergism as "a joint action of two materials, such that the total effect is greater than the sum of the two effects when each is used alone." He further stated, "If the effect of the combination can be shown to exceed significantly the action expected from similar joint effect, synergism is strongly indicated." Table 5 presents the increased mortality of the toxaphene-DDT mixture compared with the expected mortality for two compounds of similar action. The increase in mortality ranged from 60 to 100% for the various doses. Such increase meets the requirements set forth by Wadley for synergistic action.

Exposure of resistant boll weevils to a residual film of mixtures of insecticides in which DDT was one of the chemicals resulted in greater activity for all mixtures than for the insecticides alone. The greatest increase resulted from mixtures of toxaphene-DDT. This is in agreement with results obtained when the insecticide mixtures are applied topically to the thorax of the boll weevil.

Although the toxaphene-DDT mixture exhibits synergistic activity against resistant boll weevils, the combination was not as active against resistant boll weevils as toxaphene alone against susceptible boll weevils. The greater amount of the toxaphene-DDT mixture required to control resistant boll weevils than toxaphene alone for susceptible weevils is in agreement with reports by Perry & Hoskins (1951), and March *et al.* (1952) for chemicals showing synergistic action against house flies. Resistance to DDT-synergist combination was rapidly developed by house flies in the laboratory to levels as high as those developed to DDT alone before selection (March *et al.* 1952).

Absorption of DDT into the boll weevil is approximately the same for DDT alone as when applied in a mixture with toxaphene. The rate of absorption of toxaphene is unknown. Separate application of toxaphene and DDT to different sites of the weevil was as effective as a single application of the mixture. It appears that enhancement of penetration of one or both insecticides is not the factor involved in its increased efficiency. Perry & Hoskins (1951) found that, with DDT-synergist combinations, penetration of DDT was slightly reduced.

The application of DDT even as late as 96 hours after the application of toxaphene resulted in high mortality of weevils; where toxaphene followed toxaphene, mortality among weevils was low.

Boll weevils treated with mixtures of insecticides containing DDT failed to metabolize DDT as rapidly as when treated with DDT alone. Metabolism of absorbed

Table 4.—DDT and DDT metabolites recovered from chlorinated hydrocarbon resistant boll weevils treated topically with toxaphene on the thorax and DDT on the abdomen.[a]

Hours	μg. DDT External	Per Cent DDT External	μg. DDT Internal	Per Cent DDT Internal	μg. DDE Internal	Per Cent DDE Internal	μg. Internal DDT Metabolized	Per Cent Internal DDT Metabolized	Per Cent Internal DDT Metabolized to DDE	μg. Recovered DDT+ DDE	Per Cent Recovered DDT+ DDE
0	4.90	98.0								4.90	98.0
7	3.24	64.8	0.94	9.8	0	0	1.27	72.7	0	3.73	74.6
24	2.83	56.7	0.72	13.8	0.09	1.8	1.49	68.7	3.97	3.55	71.0

[a] 48 hour mortality = 67 ± 9%. Sixty weevils analyzed per time interval. Results are expressed on a per weevil basis.

Table 5.—Results of a toxaphene-DDT mixture applied topically to resistant boll weevils.

Insecticides in Mg./Gm.		Toxaphene Equivalent	Per Cent Mortality		Per Cent Increase
Toxaphene	DDT		Actual	Interpolated	
0.198	0.099	0.479	24	15	60
0.355	.177	0.856	38	20	90
0.769	.385	1.858	61	30	103
1.515	.758	3.659	73	41	78

DDT was slowest when DDT was applied in a mixture with toxaphene. Where DDT was applied in a mixture with endrin, metabolism of DDT was slowed to some degree but not as much as in the toxaphene-DDT mixture. The decreased rate of degradation of DDT allows for its accumulation in amounts sufficient to account for the increased mortality. Blum *et al.* (1959) showed that the boll weevil is not inherently immune to DDT. When injected the dosage of DDT required for an LD_{50} is approximately 0.5 μg per weevil. This is not appreciably higher than that required for LD_{50} of DDT applied topically to susceptible house flies (Decker & Bruce 1952). The amount of internal DDT metabolized 7 hours after application varied from 71.2% for the toxaphene-DDT mixture to 82.8% for DDT alone.

The fate of toxaphene in the boll weevil is unknown.

As previously stated, a mixture of toxaphene-DDT gave greater mortality of resistant boll weevils than can be expected from two insecticides for similar action. Thus the mixture of toxaphene-DDT exhibits synergistic action on resistant boll weevils. The mechanism by which this response is exhibited is not understood. Four possible mechanisms are suggested: (1) the interference of the DDT detoxification mechanism by toxaphene allows DDT to reach the site of action; (2) the interference of toxaphene detoxification by DDT allows toxaphene to reach the site of action; (3) the simultaneous interference in detoxification of both chemicals; (4) formation of a chemical complex between the two chemicals.

References Cited

Blum, M. S., N. W. Earle, and J. S. Roussel. 1959. The absorption and metabolism of DDT in the boll weevil (*Anthonomus grandis* Boh.). (In press.)

Decker, G. C., and W. N. Bruce. 1952. House fly resistance to chemicals. Amer. Jour. Trop. Med. and Hyg. **1**: 395–403.

Gaines, J. C., H. A. Dean and Read Wipprecht. 1951. Tests of insecticides for control of cotton insects during 1950. Jour. Econ. Ent. **44**: 367–72.

March, R. B., R. L. Metcalf and L. L. Lewellen. 1952. Synergists for DDT against insecticide-resistant house flies. Jour. Econ. Ent. **45**: 851–60.

Perry, A. S., and W. M. Hoskins. 1951. Synergistic action with DDT toward resistant house flies. Jour. Econ. Ent. **44**: 839–50.

Roussel, J. S., and D. F. Clower. 1955. Resistance to the chlorinated hydrocarbon insecticides in the boll weevil (*Anthonomus grandis* Boh.). Louisiana Agric. Expt. Sta. Circ. **41.**

Wadley, F. M. 1945. The evidence required to show synergistic action of insecticides and a short cut in analysis. U. S. Dept. Agric. Bur. Ent. and Plant Quar. **ET-223.**

Summer Pupation of the European Corn Borer and the Seasonal Temperature[1]

H. C. Chiang[2] and A. C. Hodson[3]

Abstract

In an 11-year study of the population ecology of the European corn borer (*Pyrausta nubilalis* (Hbn.)) in southern Minnesota, a correlation has been found between the pattern of the seasonal temperature and the proportion of the first-generation mature larvae which pupated during the summer. This correlation may be useful in predicting the potential of the second-generation borer infestation.

The European corn borer overwinters as a mature larva. All the healthy and normal larvae pupate in the spring, emerge as adults shortly after, and then oviposit on corn plants. The larvae reach maturity about midsummer. Various proportions of them may pupate, emerge as moths, and oviposit to produce second generation larvae. Those that do not pupate remain in a state of diapause until the following spring. Other things being equal, the level of infestation of the second generation will be proportional to the per cent of the mature larvae which pupate during midsummer.

It is known that pupation of borers is influenced by temperature. Under controlled constant temperatures, Kozhantshikov (1938) showed that all borers entered diapause at temperatures below 20° C., no borer entered diapause at temperatures above 26° C. and variable proportions of the borers entered diapause in the intermediate range of temperatures. Records secured in southern Minnesota in an 11-year period showed a correlation between the per cent of summer pupation and the seasonal temperature under field conditions. Consequently an attempt has been made to predict the degree of summer pupation to be expected on the basis of temperature summation.

Results.—The results reported in this paper were col-

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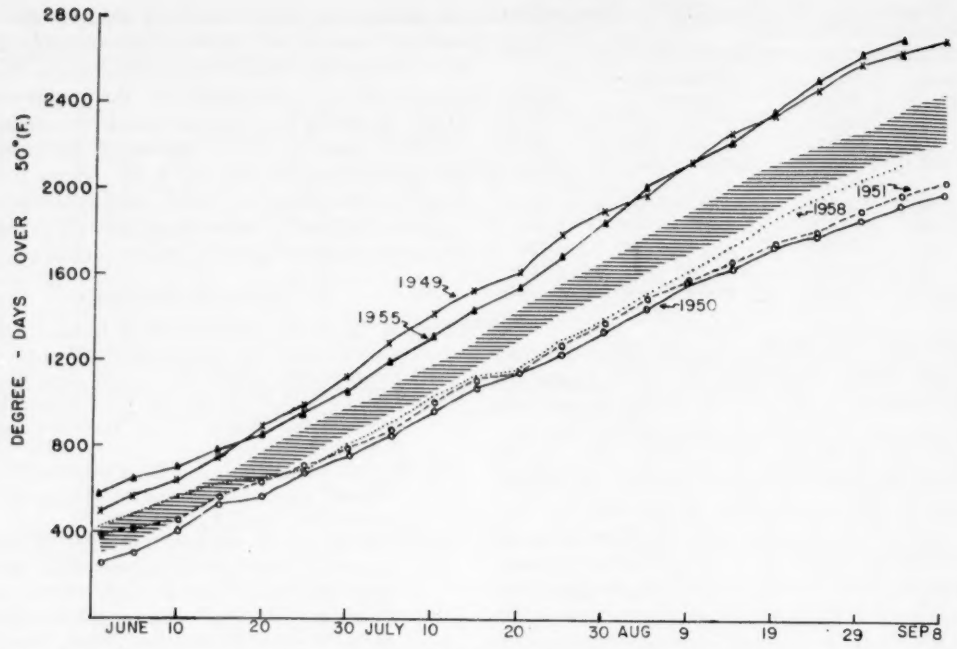

FIG. 1.—Cumulative degree-days over 50 (F), 1948 to 1958, inclusive, Waseca, Minnesota. 1949 and 1955 were above average, 1950 and 1951 below average. The hatched band represents the intermediate range including 1948, 1952, 1953, 1954, 1956 and 1957.

lected in 1948 to 1958 inclusive, at the University of Minnesota Southern Experiment Station, Waseca, Minnesota. One field which was planted at a time normal for the region was under observation each year. The varieties of corn were all Minhybrids commonly grown in the area. A number of plants were dissected at intervals during the larval development in order to determine the maximum per cent of the mature larvae which pupated during the summer. The pupation and other pertinent information on the fields are presented in table 1. The data show that summer pupation varied from 5.5 to 100% during the 11-year period.

The cumulative degree-days over 50° F. for the 11 seasons are shown in figure 1. The cumulation was started from the early spring, but was continued only until early September. Fifty degrees was selected as the threshold temperature on the basis of the studies by Caffrey & Worthley (1927) and Apple (1952). It may be seen that the cumulative figures for 1949 and 1955 were above average and for 1950 and 1951 were below average. 1958 was below average until early August when the season warmed up and approached the intermediate range toward the latter part of the season. The other years varied within a limited intermediate range, as shown by the hatched band.

DISCUSSION.—It is interesting to note (table 1) that in both of the warmer years the summer pupation exceeded 90% and in the 3 cooler years the summer pupation fell to 10% or lower. The per cent pupation in the other years fell in an intermediate range, although it did not correspond precisely with the temperature patterns in all individual years. This is perhaps not too surprising since many other factors may also be effective in different years. It has been shown for many insects that the onset of diapause may be affected by photoperiod (Lees 1955). In the present case, the effect of low seasonal temperature may be in part a matter of delaying the larval development so that the larvae will be exposed to longer nights. It is also significant that even though the season warmed up during August in 1958, the pupation was not increased. This fact suggests that the temperature of the early season was more important, or that photoperiodicity might have been involved.

This correlation between the seasonal temperature as shown by the cumulative degree-days over 50° F. and the per cent of pupation may be of practical value. The data presented suggest that the extent of summer pupation which normally does not become apparent until August may be estimated well in advance on the basis of tempera-

Table 1.—Variety, date of planting, and per cent of summer pupation in 11 fields of hybrid corn, 1948 to 1958.

YEAR[a]	VARIETY (MINHYBRIDS)	DATE OF PLANTING	PER CENT OF PUPATION
1955	411	May 12	100.0
1949	505	May 3	92.0
1956	507	May 17	66.7
1957	412	May 7	53.3
1954	406	May 10	48.6
1953	506	May 13	47.6
1952	408	May 15	28.6
1948	505	May 15	17.5
1958	415	May 10	10.0
1951	503	May 3	8.7
1950	504	May 12	5.5

[a] The years are arranged according to the per cent of pupation.

ture patterns, at least to the extent of predicting whether the pupation will be extremely high or extremely low. From a practical standpoint, the distinction between the extremes and the median range is perhaps more significant than the finer distinctions within the median range. This advanced estimate, in combination with the knowledge of the level of the population prevailing in July will enable the field entomologists engaged in borer control work to predict the potential of the second-generation infestation.

In retrospect, high percentages of summer pupation would have been predicted early in July in both 1949 and 1955 on the basis of the temperature patterns. Since the first-generation larval population was high in 1949, the potential of second-generation infestation would have been predicted to be extremely high for that year, and it was. In 1955, however, the larval population was extremely low, thus the potential of the second-generation infestation would have been predicted correctly to be limited in spite of the high per cent of pupation. On the other hand, extremely low summer pupation would have been predicted early in July in 1950, 1951, and 1958. Thus regardless of how high the July borer populations might have been, the potential of the second-generation infestation would have been predicted to be extremely limited in these 3 years, and all three predictions would have been confirmed by the actual developments during the respective seasons.

While the general correlation shown in the present discussion is clear, the specific temperature levels may not be valid beyond the area studied for the following reasons. It is general knowledge that pupation is affected by the genetical makeup of the borer populations. Thus populations of different proportions of univoltine and multivoltine strains may respond differently to a given temperature pattern. Furthermore, there are some indications that the genetical constitution of the host plant may also influence pupation of the borer (Holdaway & Chiang, unpublished data).

An incidental point might be mentioned here. The fact that the proportion of pupation varied from less than 10% to more than 90% depending upon the seasonal temperature leads one to question whether the rigidly fixed univoltine strain of corn borer is present in southern Minnesota at all.

REFERENCES CITED

Apple, J. W. 1952. Corn borer development and control on canning corn in relation to temperature accumulation. Jour. Econ. Ent. **45**: 877–9.

Caffrey, D. J., and L. H. Worthley. 1927. A progress report on the investigations of the European Corn borer. U. S. Dept. Agric. Bull. **1476.**

Kozhantshikov, I. W. 1938. Geographical distribution and physiological characteristics of *Pyrausta nubilalis* (Hbn.) (in Russian, English summary) Zoologicheskii Zhurnal (Moscow) **17**: 246–59.

Lees, A. D. 1955. The physiology of diapause in Arthropoda. Cambridge University Press, Cambridge, England.

Control of *Macrosiphum barri* Essig and Its Damage to Lettuce Seed Plants[1]

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ABSTRACT

Repeated field applications of selected insecticides to seed lettuce satisfactorily controlled infestations of the lettuce seed stem aphid, *Macrosiphum barri* Essig. These treatments also gave a very significant reduction of an infestation by the two-spotted spider mite (*Tetranychus telarius* (L.)), but they did not give an adequate reduction of lettuce mosaic.

A threefold increase in yield of lettuce seed was obtained by the use of repeated applications of parathion sprays and dusts for control of the lettuce seed stem aphid. This increased yield was significantly higher than that obtained from plots treated with other materials, and was judged to be economically satisfactory. There was also a very significant increase in the weight and size of the lettuce seeds. This was also confirmed by cage tests. This aphid caused a reduction of about 66% in yield of lettuce seed obtained from untreated plots.

It was possible to demonstrate that these stem aphids caused a lettuce seed loss of as much as 59%, when artificially infested plants were grown in field cages. However, the exact degree of infestation necessary to produce economic loss of seed was not established.

The feeding of this aphid also produced a significant reduction in the number of normal seedlings. In addition, there was a decrease in the mean emergence period of the aphid-damaged seeds, indicating a more rapid germination. A significant increase in damage to cotyledons of the seedlings was obtained from the aphid-damaged seeds, which showed that this aphid is one cause of "red cotyledon" of lettuce seedlings.

The lettuce seed stem aphid, *Macrosiphum barri* Essig,[3] often damages lettuce seed plants in the Sacramento valley of California. Control has been effected by applications of dusts containing nicotine, TEPP, malathion or parathion. The best possible choice of insecticides or number of applications necessary have not been

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[3] Determined by Miss Louise M. Russell, Insect Identification and Parasite Introduction Laboratories, U. S. Department of Agriculture. Later determinations were kindly made by Dr. R. C. Dickson, University of California, Riverside.

established with certainty. This difficulty is additionally confused in this area by the presence of lettuce mosaic, which apparently is spread early in the season primarily by the green peach aphid, *Myzus persicae* (Sulz.). As a result, seed companies have been forced to isolate lettuce seed plantings and to apply many insecticidal treatments during a season.

Heretofore, the actual amount of damage to lettuce seed plants attributable to the feeding of the stem aphid has been unknown. Abnormal cotyledon seedling symptoms called "red cotyledon" have been noted in some lettuce seed plantings; but its causative agent remained undetermined. Portman & Manis (1954) suggested control when four or five aphids were present on 2 inches of the seed stems. Otherwise, very little has been published on the control or injury by this lettuce aphid.

Work on this problem was begun in 1956 at Davis, California. Replicated field plots were established in a field of seed lettuce affected by mosaic. Spray applications were begun early in the growing season for possible reduction of mosaic. Control of the stem aphid was evaluated, and the yield and germination of the lettuce seed obtained were determined.

Exploration for possible effects of the stem aphids on the yield and viability of the seed and on abnormal seedlings of the next generation was emphasized during 1957. This facet of the work involved the use of field plants which were caged and artificially infested with aphids.

APHID CONTROL EXPERIMENTS.—*Procedure.*—Lettuce seed of the Great Lakes variety (with about 1% of seedborne mosaic) was planted on March 10, 1956. The plants were thinned once, irrigated several times, deheaded once, and fertilized once. A good bolting lettuce seed field was produced by July 1. This field was divided into 30 plots for six treatments replicated five times each. Every plot contained three double-row beds 50 feet long. Insecticides were applied only to plants in the two rows of the center bed.

Each of the five treatments listed in table 1 included six sprays applied on the following dates: April 16, April 29, May 11, May 28, June 12, and June 27. Two applications of dusts were thereafter applied to all but two of the plots on July 13 and August 1. The sprays were applied at 50 gallons per acre with a knapsack sprayer having two flat Teejet #80015 nozzles per row. The desired dosage of active ingredient per acre was applied by manipulating concentration and time of flow. The dusts were applied thoroughly at 40 to 50 pounds per acre with a hand rotary duster.

Aphids were collected each week from white enameled pans set into the soil in the central bed of each check plot. These pans contained only an aqueous solution of potassium chromate, which provided the yellow color attractive to the aphids. These aphids were counted and classified to genus within a few days after each collection.

The amount of lettuce mosaic present in treated and untreated plots was determined on May 31, 1956, three days after the fourth spray was applied. Dr. J. E. Welch, Department of Vegetable Crops, University of California, Davis, assisted with the identification of the virus-infected plants.

The aphid counts on the lettuce seed plants were made on August 3, which was 2 days after the last dust was applied. Twenty-five plants per replication were rated according to the severity of infestation of the stem aphid per plant as follows: 0, clean (no aphid colonies); 1, light (1 aphid colony); 2, moderate (2 to 3 aphid colonies); 3, severe (4 to 6 aphid colonies); and 4, very severe (7 or more aphid colonies). It was thereby possible to calculate an index of severity of infestation for each replication by dividing the sum of the products of the number of plants in each class and its class number by the total plants checked.

Yields were based on samples of 10 aphid-damaged lettuce seed plants per replication. The plants to be stripped of seed were selected on August 17. The secondary seed branches or spikes of each plant were gathered and tied into a compact bouquet with loops of twine placed be-

Table 1.—Effects of insecticides applied to lettuce plants on lettuce mosaic, lettuce seed stem aphids, yield of clean seed, weight of seeds, and on the two-spotted spider mite. Davis, California, 1956.[a]

Treatments[b] and Active Ingredient per Acre	Per Cent of Plants with Mosaic (May 31)	Aphid Infestation (August 3)		Yield of Clean Seed (Sept. 5)		Weight of 100 Seeds (Gm.)	No. of Mites per Leaf (Aug. 6)
		Index of Severity	Per Cent Control	Grams per Plot	Pounds per Acre		
Spray, 1 lb. parathion+ Dust, 2% parathion	—	0.04	98	148	814	0.093	6.2
Spray, 0.5 lb. demeton+ Dust, 10% DDT−4% malathion	—	0.02	99	123	677	0.086	9.6
Spray, 0.5 lb. lindane+ Dust, 1% lindane−4% malathion	18.1	0.16	91	101	557	0.086	11.3
Spray, 0.5 lb. demeton+ Dust, 1% lindane	24.0	0.26	85	113	621	0.084	26.6
Spray, 1 lb. parathion	17.9	0.34	81	115	634	0.086	46.5
Check	28.0	1.73	—	50	276	0.077	75.8
L.S.D. at 5% level		0.35	—	14	—	0.004	18.2
at 1% level		0.48	—	19	—	0.005	23.9

[a] The values given are expressed as averages.
[b] There were six sprays plus two applications of dusts during the period from April 16 to August 1.

neath the seeds and flowers. It was essential to shake (shag) each plant into a straight-sided 4-gallon can. Three to five shakings per plant were necessary, depending upon the degree of aphid damage per plot. It was then possible to compute the yield per acre from the rate of lettuce plants used per acre.

The seed was cleaned in a small office-type Clipper seed cleaner with a minimum flow of air. Both the cleaned seed and the uncleaned, light seed were saved. The seeds were counted into lots of 100 per replication, weighed, and the number of seeds per ounce was calculated. Each lot was tested for germination on blotting paper soaked in distilled water. The blotters were placed in sandwich boxes and placed in a room at a temperature of 68° F. and relative humidity of 75 to 80%. The final count for germination included a tally of abnormal seedlings. Seedlings were considered abnormal if a brown, brownish-red, or red spot occurred on the basal half of the cotyledon or stem or both. The mean emergence period was also calculated for each germination test.

Greenhouse germination tests were run on the cleaned seed in an attempt to determine whether treatments which reduced numbers of aphids also reduced the incidence of seedborne mosaic. Only the check and the best of the aphid treatments from the field experiments were examined in this respect. Seeds so tested were planted in flats, at 25 seeds per row and 20 rows per field plot.

Results.—The data presented in table 1 show that repeated applications of selected pesticides to seed lettuce, during the period of attack by the lettuce seed stem aphid, significantly reduced the population of these aphids. It was also evident from these data that the pest greatly depressed the yield of lettuce seed, and that the weight and size of the seeds produced was decreased.

All of the treatments applied in the field plots produced very significant reductions in infestation by this aphid. However, there was apparently no meaningful difference between the "Indices of Severity" computed for the five treatments applied. According to this criterion, six demeton sprays plus two dustings of DDT-malathion were slightly better than six parathion sprays followed by two dustings of parathion. Both of these treatments appeared to give considerably more aphid control than any of the other treatments tested. Six parathion sprays without supplemental dustings gave the poorest aphid control.

The data also show that the applications of dust were useful supplements to the spray treatments. The parathion and DDT-malathion dusts appeared to give about equal results, and both dusts were superior to lindane or lindane-malathion dusts. None of the materials tested were persistent enough to fully protect the lettuce seed plants for the total period of hazard.

Inspection for lettuce mosaic, which was made on May 31, indicated that the first four sprays of parathion and lindane had reduced the incidence to this virus disease. However, the percentage of infected plants was still high, and the amount of reduction was not sufficient to indicate that the treatments resulted in a practical control of mosaic. A series of demeton sprays did not appreciably reduce the number of mosaic-infected plants.

The difference in yield of clean seed due to insecticidal treatments were striking. The parathion spray plus dust treatment (table 1) produced an almost threefold increase in yield of lettuce seed, which was a satisfactory and economical gain for this seed crop. Thus, the yields are more outstanding than the aphid count indicated that they might be. This is probably due to the fact that a succession of aphid counts was not made, so that the overall aphid reduction by the treatments was not completely evaluated.

The control experiments on lettuce seed plants demonstrated that the lettuce seed stem aphid is capable of causing as much as 66% loss of seed. Treated plants, particularly those treated with parathion, produced larger seeds than untreated plants. This resulted in a variation in the number of seeds per gram from a high of 1299 in the untreated check to a low of 1075 in the parathion treatment.

The results of standard laboratory tests for germination of the cleaned and uncleaned seeds were not significant, and are not given in tabular form. These data showed that there was no apparent decrease in viability of cleaned lettuce seeds from the control plot, and that there was no apparent increase in the number of abnormal seedlings. The uncleaned, light seed showed a significant decrease in germination and an increase in the number of abnormal seedlings as compared with clean seed; but there was no difference between the treated lots. However, the lighter seed of the controls did show a slight but nonsignificant increase in mean emergence period. Germination tests in greenhouse flats showed no difference in seed viability between treatments. Furthermore, the best aphid treatment did not produce any reduction in the number of mosaic seedlings. This may have been due, at least in part, to the relatively small number of seeds tested and indexed. Thousands of seedlings are normally required for proper indexing of seedborne lettuce mosaic.

ASSESSMENT OF CROP DAMAGE.—*Procedure.*—Infestations of lettuce seed stem aphid were manipulated on caged lettuce seed plants in an attempt to relate the type and amount of crop damage to differing levels of infestation. Bolting field plants were caged individually *in situ* early in July. These were sprayed thereafter with a 0.015% spray dilution of a commercial preparation containing pyrethrum and rotenone, before artificial infestations were attempted. (Actually, the spray dilution used contained 0.00006% pyrethrins plus 0.00019% rotenone, as well as 0.00019% of other cube resins, 0.0023% pine oil, and 0.003% of petroleum solvents.) Plants caged for checks were sprayed with the pyrethrum-rotenone mixture once each week until the experiment ended.

Prepared plants were artificially infested with apterous females of *M. barri*, on July 26, 1957. One aphid was released on each of 10 plants, four aphids on each of a second series of 10 plants, and eight aphids on a third series of 10 plants. It was hoped that plants receiving different numbers of aphids would later build up infestations roughly proportional to the numbers initially introduced.

Fifty-six days later, on September 20, the plants were cut and taken indoors to dry within their cages. When the plants were dry the cages were opened over a tub to recover shattered seeds. At this time the number of secondary seed branches (or spikes) per plant were counted and the plants threshed by hand. All of the seeds recovered from each plant were carefully cleaned and weighed. Lots of 100 seeds were germinated as already described.

Table 2.—The average yield of lettuce seed and weight of seeds obtained from plants artificially infested with the lettuce seed stem aphid. Davis, California, 1957.

Number of Aphids Introduced per Plant (July 26)	Yield (Sept. 20)			Weight and Size of 100 Seeds[a]	
	Grams per Secondary Branch	Pounds per Acre	Per Cent Loss	Weight in Grams	Number of Seeds per Ounce
0	1.40	723	—	0.097	29,226
1	0.81	420	42	.083	34,156
4	0.58	299	59	.075	37,799
8	0.74	384	47	.080	35,436
L.S.D. at 5% level	0.30	—	—	.002	—
at 1% level	0.43	—	—	.003	—

[a] The weight of the seeds and number of seeds per ounce indicate size of seeds obtained.

Table 3.—The average number of lettuce seedlings, mean emergence period of the lettuce seeds, and severity of damage to seedling cotyledons obtained from plants artificially infested with the lettuce seed stem aphid. Davis, California, 1957.

No. of Aphids Introduced per Plant	Per Cent of Emergence		Seedling Cotyledon Damage by Aphids	
	Normal Seedlings	Mean Period in Days	Index of Severity	Per Cent Increase
0	87.6	4.1	0.12	—
1	72.8	3.2	.34	64
4	69.8	3.8	.45	73
8	66.2	3.5	.49	75
L.S.D. at 5% level	11.0	0.6	0.18	—
at 1% level	15.4	0.8	0.25	—

Each germination lot was examined and counted at frequent intervals in order to determine a mean emergence period as well as per cent viability. The seedlings were closely examined for symptoms of cotyledon or root damage. The severity of cotyledon seedling damage (*i.e.*, "red cotyledon") was rated quantitatively as follows: 0, none; 1, light; 2, moderate; 3, severe; and 4, very severe.

Results.—The plants that were initially infested with one aphid each tended to develop light to moderate infestations during the course of the experiment. Those that were initially infested with four aphids and those that received eight aphids developed moderate to severe infestations. These two groups of plants were not distinguishable in the final stages of the experiment. The control plants did not develop aphid infestations in any of five replications.

All of the lettuce seed plants artificially infested with lettuce seed stem aphid showed very significant reductions in weight and size of seeds and in total yield (table 2). However, the groups of caged plants initially receiving different numbers of aphids did not yield significantly different amounts of seed. Maximum crop loss calculated for the artificially infested plants was about 59%. This value closely approximates the maximum per cent crop loss obtained from the infested field plots of the control experiments described above.

The effects of the aphids on the per cent germination, mean emergence period, and incidence of cotyledon injury are shown in table 3. In general, seeds from all of the infested groups of plants produced significantly smaller numbers of normal seedlings than the seeds from aphid-free check plants.

There was a significant but unanticipated decrease in the mean emergence period for lots of seed from the aphid-infested plants. This indicated that the feeding of this aphid can also cause a stimulation or "quickening" of seed germination.

The incidence of cotyledon damage was much greater among seedlings produced by seeds from aphid-infested plants than from control seeds. The cotyledon damage increased according to the level of aphid infestation on the parent plants, and even the lightest infestation resulted in cotyledon injury of economic significance. This showed that the aphid is at least one cause of "red cotyledon" damage to lettuce seedlings.

DISCUSSION.—The lettuce seed stem aphid was collected in moderate numbers during April and May, 1956, with a first generation peak during the last of April. There were small numbers of this aphid in the lettuce seed field during June and the first part of July. They were building up fast by July 27, and large numbers were present and well established in all of the untreated checks by August 3. These aphids increased further thereafter, and resulted in a high percentage of infested lettuce seed plants. The green peach aphid was also collected in the traps in April and May, but it was about one-half as abundant as the lettuce seed stem aphid. The green peach aphid also reached its peak at the end of April; but the last of these aphids were collected on June 18. Thus, the green peach aphid was probably a major factor in the spread of lettuce mosaic during the early spring, but disappeared by about the middle of June in this area.

During the course of these investigations an infestation of two-spotted spider mite, *Tetranychus telarius* (L.), developed on a few of the lettuce seed plants. Therefore, the average number of live mites per leaf for each treatment is also given in table 1. All of the treatments resulted in a highly significant reduction in numbers of mites. The plots treated with a succession of parathion sprays and dusts yielded leaf samples with the lowest average number of mites per leaf. The least reduction of mites per leaf was obtained in the plot which received six parathion sprays but no dusts.

The intended purpose of the chlorinated hydrocarbon and phosphate combination treatments was to control both aphids and lygus bugs. However, very few lygus bugs were attracted to the lettuce seed field and only a few were collected in the bait pans. Hyaline grass bugs became rather numerous on some plants in September. Their role in the production of lettuce seed is described in a separate paper.

REFERENCE CITED

Portman, R. W., and H. C. Manis. 1954. Idaho Recommendations for Insect Control. Idaho Agric. Expt. Sta. Ext. Bull. **216.**

Effect of Methyl Bromide and Hydrocyanic Acid Fumigation on the Germination of Oats[1]

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Abstract

Two varieties of oats, Kanota and Ventura, with a graded moisture range of 8, 10, 12, and 14% were fumigated with methyl bromide in 100-cubic-foot gastight chambers at an exposure period of 72 hours. Various dosages and temperatures were used. One variety of oats, Kanota, was fumigated with methyl bromide and hydrocyanic acid under varying conditions of temperature, exposure, and dosages of fumigant. One half of the fumigated samples of seed received one fumigation; the others were fumigated twice. Two series of germination tests were made, the first within 5 days following fumigation of seeds, and the second after 84 days of postfumigation storage at 50° F.

Under the conditions of the experiments, the germination of oats was not affected by fumigation with hydrocyanic acid. Dosage, temperature, period of exposure, and the moisture content of seeds were variables found to be most important in contributing to injury from methyl bromide. Although oat seeds were relatively resistant to fumigation with methyl bromide, some injury did occur.

The possibility of injury to seeds during fumigation for the eradication of the khapra beetle, *Trogoderma granarium* Everts, led to extensive investigations on the tolerance of seeds to fumigants under various conditions. It is the purpose of this paper to evaluate several variables which may influence the germination of oats fumigated with methyl bromide or hydrocyanic acid. Results reported were obtained from studies made under controlled conditions and with proven techniques. The germination of oats was not impaired after fumigation with hydrocyanic acid and considerable tolerance to methyl bromide was demonstrated.

Materials and Methods.—*Preparation of Seed Samples.*—Two varieties of oats, Kanota and Ventura, were used in one series of tests (72-hour exposure period) with methyl bromide. Only one variety, Kanota, was used in tests throughout the study. The initial moisture content (m.c.) of Kanota oats was 8.0% and that of Ventura oats was 7.5%. The moisture content of Kanota oats ranged from 8.0% to 9.7% due to normal fluctuations in storage during the total experimental period of approximately 18 months.

Careful adjustment of moisture and conditioning of seeds resulted in the desired graded moisture range of 8, 10, 12, and 14%. Drying seeds, adding water, or the alternation of drying and addition of moisture was necessary to obtain samples of the desired moisture content.

Seeds were dried in narrow wire-screen containers placed in a forced-air oven maintained at 125 to 130° F. This temperature did not affect the germination of oat seeds. The drying period ranged up to 3 hours at any one time, but never longer. The desired moisture level and the moisture content of seeds before drying indicated the length of time seeds were to be held in the air-oven. Water was added to increase the moisture content when necessary. After drying or addition of water, seeds were conditioned in airtight polyethylene bags for 7 days at 50° F. Then seeds were blended and moisture tests were made by the air-oven method specified in the A.O.A.C. Official Methods of Analysis (Horwitz 1955) to determine the need for additional moisture adjustments.

When the moisture content of oats had reached the desired level, each lot of seeds was divided into samples of approximately 100 grams each and put into small rough-woven cotton bags. Seeds were removed from these bags only for germination tests. Each cloth sample-bag of oats was placed in an airtight polyethylene bag to prevent moisture changes while the prepared samples awaiting fumigation were held in storage at 50° F.

Fumigation of Seeds.—Test samples were removed from storage and held overnight at the desired fumigation temperature before removing airtight polyethylene bags. Seeds of all four moisture levels were placed in slatted crates inside the fumigation chambers to be fumigated together. The crates permitted thorough circulation of gases.

Fumigation experiments were conducted in 100-cubic-foot gastight chambers with continuous circulation of air within the fumatorium. Temperatures were thermostatically controlled at 50°, 70°, and 90°±1° F., but no attempt was made to control humidity. Fumigations were twice replicated.

Fumigants were applied at two dosage levels, one high and one low, throughout the study. Dosages were selected according to exposure periods and temperatures during fumigation. Seeds were exposed to fumigants for 72 hours in beginning tests. When germination was impaired at this exposure from the dosages applied, tests were made with shorter exposure periods.

The exposure periods, temperatures during fumigation, and dosages of fumigants applied are given in table 1. Concentrations of fumigants were not determined for each dosage or exposure interval. However, typical curves for the fall in concentrations of methyl bromide were given previously by Strong & Lindgren (1959a).

All seeds received an initial fumigation, and one-half of the samples were fumigated a second time 21 days after the initial exposure to test the effect of repeat fumigation. After fumigation, seeds were aerated for 24 hours, then repackaged in airtight polyethylene bags. Test samples were held in postfumigation storage at 50° F. and removed only for germination tests.

Germination Tests and Assessment of Results.—Two series of germination tests were made, the first within 5 days after fumigation of seeds, and the second after 84 days (12 weeks) in postfumigation storage at 50° F. Seeds were germinated at 68° F. in folded-paper-towel substrata.

Germination tests and seedling interpretations were made in accordance with regular methods of Official Seed

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Table 1.—Exposure periods, temperatures, and dosages of hydrocyanic acid and methyl bromide used for the fumigation of oat seeds.

Fumigant	Exposure-Hours	Temperature ° F.	Dosage (Lb./1000 Cu. Ft.) Low	High
Hydrocyanic acid	72	90	1.0	2.0
		70	1.0	2.5
		50	1.0	3.0
Methyl bromide	72	90	1.0	3.0
		70	1.5	3.0
		50	2.0	4.0
	48	90	1.5	4.0
		70	2.0	4.0
		50	2.5	5.0
	24	90	1.5	4.0
		70	2.0	4.0
		50	2.5	4.0
	8	90	2.0	5.0
		70	3.0	5.0
		50	3.0	6.0
	2	90	3.0	6.0
		70	3.0	6.0
		50	3.0	6.0

Analysts (Assoc. Off. Seed Analysts 1954), except seeds with obvious mechanical injury were not planted, and 100 seeds were used per test for each treatment replicate. Nonfumigated seeds served as control standards for comparison. The percentages of germination (normal seedlings) was the only criterion recorded for comparison of results. (See p. 131, U. S. Dept. Agric., Agric. Handbk. No. 30, 1952, for a description of normal seedlings.)

RESULTS.—Due to the large number of germination tests made during the study, over 2000 tests of 100 seeds per test, it has been necessary to condense results materially and present only a summary of essential data. The results from fumigated seeds are presented as the corrected percentages of reduction in germination, and these were calculated by extending Abbot's (1925) formula as follows:

$$\text{Corrected percentage reduction in germination} = \frac{\text{\% germination in control samples} - \text{\% germination in fumigated samples}}{\text{\% germination in control samples}} \times 100$$

The percentages of germination in control samples of the two varieties of oats used for the 72-hour exposure period to methyl bromide are summarized in table 2. The frequency at which percentages of germination occurred refers to the actual number of tests having germinations within a given range in the percentage germination out of 96 tests for each variety. Differences between the two varieties of oats in seed quality are readily apparent from the results of germination tests with control samples presented in table 2. Although counts were not made, seeds of Ventura oats were obviously more heavily infected with smut than those of Kanota. This was considered the primary reason for differences between varieties in the germination of control samples of the two varieties.

Table 2.—Frequency[a] at which percentages of germination occurred in unfumigated control samples of two varieties of oats for the 73-hour exposure to methyl bromide fumigation.

Range of Per Cent Germination	Variety of Oats Kanota	Ventura
96–100	11	0
91– 95	27	1
86– 90	41	13
81– 85	16	27
76– 80	1	31
71– 75	0	16
66– 70	0	6
61– 65	0	1
56– 60	0	1

[a] Expressed as the number of times in 96 germination tests for each variety.

Results from germination tests with control samples of Kanota oats for all tests are summarized in table 3. The frequency at which percentages of germination occurred are given for each graded moisture range. These data indicate small differences which may be attributed to procedures followed in the preparation of seed samples. However, the number of tests with germinations above 90% is very nearly the same for samples of all moisture levels.

Hydrocyanic Acid Fumigation.—Exposure of Kanota oats with a graded moisture range of 8, 10, 12, and 14% to hydrocyanic acid fumigation for 72 hours at temperatures and dosages listed in table 1 did not result in significant reduction in germination. For this reason, only a summary of results for the extremes in treatments are given in table 4. It is obvious from these data that further discussion is not justified.

Methyl Bromide Fumigation.—Results from the first series of germination tests (seeds planted within 5 days after fumigation) are summarized in tables 5 to 9 as the corrected percentages of reduction in germination. Oat seeds were found to be quite tolerant to methyl bromide as compared with wheat (Strong & Lindgren 1959a), but slightly less tolerant than barley (Strong & Lindgren 1959b). Differences between treatments indicate that several variables considered in this study contributed to some reduction in germination after fumigation with methyl bromide. This is discussed more fully below.

DISCUSSION OF RESULTS FROM METHYL BROMIDE FUMIGATIONS.—Seven variables considered of importance in this study are listed and discussed separately in regard to the importance of each variable in contributing to the injury of oat seeds from methyl bromide fumigation.

Varietal Differences.—Differences observed between

Table 3.—Frequency[a] at which percentages of germination occurred in unfumigated control samples of Kanota oats for all fumigation tests.

Moisture Content (%)	Per Cent Germination (Ranges) 76–80	81–85	86–90	91–95	96–100
8	0	6	18	28	92
10	0	3	11	33	97
12	0	4	15	32	93
14	1	3	16	46	78

[a] Expressed as the number of times in 144 germination tests for each moisture range.

Table 4.—Corrected percentages of reduction in the germination of Kanota oats after two fumigations with hydrocyanic acid for 72 hours at three temperatures and varying dosages.

Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.		
	90° F.—2.0	70° F.—2.5	50° F.—3.0
	Per Cent Reduction in Germination		
8	0.0	2.1	0.0
10	0.0	3.2	0.0
12	2.1	3.7	0.0
14	1.6	3.7	1.1

varieties in the data presented in table 2 from germination tests with control samples of Kanota and Ventura oats were attributed to differences in seed quality due to smut infection of seeds. The possibility of an extraneous influence on results from the smut infection in Ventura oats was sufficient reason, but not the only reason, to discontinue this variety in tests after completion of initial tests with an exposure period of 72 hours to methyl bromide.

Comparisons between the two varieties of oats in susceptibility to methyl bromide may be made from the data presented in table 5. It is difficult to attribute much importance to varietal susceptibility to methyl bromide from the small differences observed in table 5 between the corrected percentages of reduction in germination of the two varieties. Somewhat larger differences were observed between varieties in germination tests with control samples (table 2). Thus, investigation of a wide range of oat varieties for susceptibility to methyl bromide did not appear to be urgent. For this reason, only Kanota oats was used in all experiments and results with this variety are considered representative for the species.

Table 5.—Corrected percentages of reduction in the germination of two varieties of oats after one and two methyl bromide fumigations for 72 hours at various temperatures and dosages.

No. of Fumigations	Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.					
		90° F		70° F.		50° F.	
		1.0	3.0	1.5	3.0	2.0	4.0
		Per Cent Reduction in Germination					
		Kanota					
1	8	21	26	9	19	0	1
	10	14	27	12	23	3	19
	12	17	26	20	21	5	13
	14	19	44	24	29	4	19
2	8	18	14	16	26	2	6
	10	17	21	16	25	0	21
	12	18	26	19	18	11	22
	14	17	40	13	38	13	19
		Ventura					
1	8	0	13	5	13	0	3
	10	8	14	15	15	0	0
	12	14	10	23	25	3	12
	14	22	34	48	52	0	9
2	8	9	11	11	19	0	7
	10	14	20	12	19	1	6
	12	13	12	12	13	6	17
	14	15	37	34	40	8	18

Table 6.—Corrected percentages of reduction in the germination of Kanota oats after one and two methyl bromide fumigations for 48 hours at various temperatures and dosages.

No. of Fumigations	Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.					
		90° F.		70° F.		50° F.	
		1.5	4.0	2.0	4.0	2.5	5.0
		Per Cent Reduction in Germination					
1	8	9	32	12	23	1	7
	10	11	19	13	26	2	13
	12	10	20	19	28	6	22
	14	13	27	32	46	6	18
2	8	19	20	21	26	17	27
	10	20	23	19	21	9	19
	12	18	34	24	22	16	22
	14	12	31	22	42	26	46

Comparisons between temperatures cannot be made in all sets of data since dosages usually were increased with decreases in temperature. An effort was made, however, to allow an opportunity to isolate temperature from

Moisture Content of Seeds.—Results from germination tests with oat seeds of a graded moisture range (8, 10, 12, and 14%) following fumigation with methyl bromide indicate slight decreases in the percentages of germination with increases in the moisture content of seeds (tables 5 to 9).

Period of Exposure to Fumigant.—The results presented in tables 5 to 9 suggest that as periods of exposure are decreased germination injury attributable to methyl bromide fumigation decreases.

Temperature During Fumigation.—In general, where seeds were affected by methyl bromide fumigation, increases in temperature resulted in increasing percentages of reduction in germination (tables 5 to 9). Completely valid

Table 7.—Corrected percentages of reduction in the germination of Kanota oats after one and two methyl bromide fumigations for 24 hours at various temperatures and dosages.

No. of Fumigations	Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.					
		90° F.		70° F.		60° F.	
		1.5	4.0	2.0	4.0	2.5	4.0
		Per Cent Reduction in Germination					
1	8	4	24	2	12	4	1
	10	14	31	5	26	1	3
	12	16	20	10	23	0	5
	14	12	27	19	18	2	13
2	8	10	29	8	19	2	3
	10	14	29	11	27	3	10
	12	21	25	15	21	6	14
	14	20	20	17	25	9	18

Table 8.—Corrected percentages of reduction in the germination of Kanota oats after one and two methyl bromide fumigations for 8 hours at various temperatures and dosages.

No. of Fumigations	Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.					
		90° F.		70° F.		50° F.	
		2.0	5.0	3.0	5.0	3.0	6.0
		Per Cent Reduction in Germination					
1	8	0	6	0	0	0	0
	10	6	16	0	7	0	4
	12	2	12	5	7	0	2
	14	3	18	0	3	0	0
2	8	0	16	5	9	0	2
	10	8	21	8	6	3	5
	12	8	18	5	13	2	5
	14	7	22	4	17	1	9

Table 9.—Corrected percentages of reduction in the germination of Kanota oats after one and two methyl bromide fumigations for 2 hours at various temperatures and dosages.

No. of Fumigations	Moisture Content of Seeds (%)	Fumigation Temperatures and Dosages in Lb./1000 Cu. Ft.					
		90° F.		70° F.		50° F.	
		3.0	6.0	3.0	6.0	3.0	6.0
		Per Cent Reduction in Germination					
1	8	0	0	2	0	2	2
	10	5	5	3	4	0	0
	12	6	4	0	0	0	0
	14	0	0	2	5	4	0
2	8	3	2	1	0	0	2
	10	3	0	1	3	0	0
	12	0	0	1	3	1	1
	14	2	1	1	1	0	0

other variables. Results are presented in table 7 for fumigations with 4.0 pounds of methyl bromide per 1000 cubic feet at each of three temperatures for 24 hours. In this instance, differences between 50° F. and 70° F. are greater than those between 70° F. and 90° F.

Dosage of Fumigant.—Paired comparisons may be made between dosage levels from the results presented in tables 5 to 9 by horizontal examination of the data. Two dosage levels, one low and one high, were considered for each set of conditions found in this study because eradication programs require somewhat higher than normal dosages of fumigant. Examples of increased injury from high dosages may be found in one or more instances in each set of data presented in tables 5 to 8; however, increasing the dosage of methyl bromide did not result in an extensive decrease in the germination of oat seeds.

Repeat Fumigation.—In some cases increased injury to germination may be observed from two fumigations with methyl bromide. In general, however, results were similar to those presented by Cobb (1958) in that two fumigations with methyl bromide did not have a profound effect on the germination of oats (tables 5 to 9).

Postfumigation Storage.—A second series of germination tests was made after seeds were held in postfumigation storage for 84 days at 50° F. Only small variations were observed in the percentages of reduction in germination between tests made immediately (within 5 days) after fumigation and those made 84 days later. Such variations were not consistent in direction; sometimes less injury was found and sometimes more in seeds planted immediately after fumigation than in seeds held for 84 days.

Results from the latter tests are not presented, as trends suggested were in agreement with those suggested by data presented in tables 5 to 9. The results from germination tests with seeds held in storage in no way disagreed with those of Cobb (1958) and agree with his conclusion that fumigation injury occurred while seeds were in contact with the fumigant, that fumigation injury was irreversible, and seeds uninjured during fumigation do not show injury later.

References Cited

Abbot, W. S. 1925. A method of computing the effectiveness of an insecticide. Jour. Econ Ent. **18:** 265–7.

Association of Official Seed Analysts. 1954. Rules for testing seeds adopted by Association of Official Seed Analysts, effective July 1, 1955. Proc. Assoc. Off. Seed Analysts, 44th Ann. Meeting.

Cobb, Rodney D. 1958. Seed germination after fumigation with methyl bromide for khapra beetle control. California Dept. Agric. Bull. **XLVII:** 1–16.

Horwitz, William, Ed. 1955. Official methods of analysis of the Association of Official Agricultural Chemists, 8th ed., Washington, D.C., A.O.A.C.

PMA and Bureau of Plant Industry, Soils, and Agricultural Engineering. 1952. Manual for testing agricultural and vegetable seeds. U. S. Dept. of Agric., Agric. Handbk. No. **30.**

Strong, R. G., and D. L. Lindgren. 1959a. Effect of methyl bromide and hydrocyanic acid fumigation on the germination of wheat. Jour. Econ. Ent. **52**(1): 51–60.

Strong, R. G., and D. L. Lindgren. 1959b. Effect of methyl bromide and hydrocyanic acid fumigation on the germination of barley. Jour. Econ. Ent. **52**(2): 319–22.

A Study of Insecticide Resistance in House Flies of Germany and France[1]

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ABSTRACT

Strains of the house fly (*Musca domestica* L.) from nine areas of Germany and France were laboratory tested to determine their susceptibility to DDT, lindane, dieldrin and malathion by topical application in acetone solutions. All strains were derived from flies which were collected in the field and reared in the laboratory until several successive generations had been tested. All strains tested were found to be significantly resistant to DDT, a Heidelberg strain having an LD-50 (lethal dose required for 50% mortality) of 71 times, La Rochelle 44 times, Orleans 36.7 times, and Munich 29.7 times as great as a non-resistant laboratory strain cited. Similarly five strains showed a moderate degree of resistance to lindane and five to dieldrin. None were shown to be significantly resistant to malathion.

During the some 14 years subsequent to the entry of allied forces onto the European Continent in 1944 large quantities of DDT have been used for control of flies and other insects of medical importance in France, Germany and other countries. During the past 5 years considerable quantities of lindane, dieldrin and also some of the organic phosphorus insecticides have come into use by the Europeans for control of various insects. Although DDT continues to be the most commonly used insecticide for control of flies and other insects in and around United States (U. S.) military installations there have been numerous instances where lindane has been used when resistance to DDT was suspected. To date neither dieldrin or the organic phosphorus insecticides have been in general use by U. S. forces on military bases in Europe.

Some degree of resistance to DDT by house flies at certain military bases has been suspected for the past several years and as early as 1953 workers in the 4th Medical Field Laboratory began collecting house flies, from several military bases for laboratory studies on the degree of resistance developed to DDT. During 1956 and 1957 the entomology section[3] of the U. S. Army in Europe (USAREUR) Medical Laboratory enlarged the scope of these studies to include lindane, dieldrin and eventually malathion.

House flies have not been in sufficient abundance at U. S. military bases to cause concern due to reasonably good sanitary procedures; however, there have been isolated cases, such as city dumps utilized by both U. S. military and indigenous populations, where resistance to both DDT and lindane has made control somewhat difficult. In some areas house flies have been exposed to various organic phosphorus insecticides, since they are manufactured and sold by several European firms. It was therefore deemed advisable to include malathion in the resistance studies reported herein, since it is one of the phosphorus insecticides of current choice by the U. S. Forces for control of flies resistant to all the chlorinated hydrocarbon toxicants.

The present study was designed to determine the dosage required for 50% mortality, hereafter referred to as the LD-50, for the above mentioned insecticides for future comparison of the degree of resistance in house flies in Germany and France.

METHOD.—Laboratory colonies were established in the summer and fall of 1956 from adult flies collected in several areas of both Germany and France. Most collections were made either at local city dumps utilized by U. S. Forces or at "piggeries" utilizing garbage from U. S. installations. At these locations the fly population has been mixed with those from the military posts through the medium of garbage trucks and other traffic and has thus been exposed to DDT and/or lindane used at the posts and frequently to insecticides used by the swine producers. Several successive generations of each such laboratory fly colony were tested for resistance to insecticides. Again in the summer and fall of 1957 adult flies were field-collected, usually from the same source as for 1956, and new laboratory colonies established for studies of comparative resistance.

Exceptions to the above collection localities are the Verdun strain which was taken as larvae from a French slaughter house about 1 mile from a U. S. military post near Verdun where slaughter house personnel stated they had used no insecticides in the vicinity and the Dankenfeld strain which was collected as adult flies in a German farm house near Wurzburg, some distance from U. S. military installations. No information is available as to history of insecticide use in the latter.

Larvae were cultured in a medium prepared in the laboratory by making a mixture of oat hulls, alfalfa meal, wheat bran, yeast tablets, malt and water (a modification of a formula used by the Orlando Florida Laboratory). Adult flies were fed on whole milk diluted one-half with water.

Female flies, 2 or 3 days old, were used in all tests. The flies were initially anesthetized with carbon dioxide and subsequently kept in a stunned condition for handling during the test by passing carbon dioxide from dry ice through a perforated holding chamber, similar to a method described for mosquitoes by Tarshis (1957). Each fly was given a dose of approximately 4 microliters of acetone-insecticide solution. The droplets were applied to the thoracic region of the fly from a $\frac{1}{4}$-ml. tuberculin syringe actuated by a stationary micrometer as described by Trevan (1922). For each insecticide, five groups of 50 flies each, from successive generations of the various strains, were used. Pre-test exposures had indicated the approximate insecticide dosage which would result in about 50% mortality. Thus, a selected series of five dilutions, each containing twice as much insecticide as the preceding one, were used to treat the five series of 50 flies

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Table 1.—Toxicity of DDT, lindane and dieldrin to nine house fly strains in Europe.

Source and Collection Date	No. of Test Series	DDT			Lindane			Dieldrin		
		Range of LD-50's	Mean of LD-50's	Ratio to Normal Flies	Range of LD-50's	Mean of LD-50's	Ratio to Normal Flies	Range of LD-50's	Mean of LD-50's	Ratio to Normal Flies
Piggery near Frankfurt, Germany, June 1957	6	1.7–12.5	5.53	16.8	0.04– .16	0.09	3.0	0.04– .16	0.08	4.0
Piggery near Heidelberg, Germany, June 1957	6	11.0–30.4	23.43	71.0	.08– .65	.43	14.3	.16–1.5	.66	33.0
Piggery near Munich, Germany, May 1957	5	5.0–25.0	9.80	29.7	.10– .18	.15	5.0	.08– .30	.20	10.0
Piggery near Landstuhl, Germany, April 1957	7	1.4– 3.0	2.04	6.2	.08– .20	.14	4.7	.04– .16	.09	4.5
Farm House, Dankenfeld, Germany, August 1956	7	1.7– 7.0	4.26	12.9	.08– .21	.17	5.7	.04– .56	.18	9.0
City Dump, La Rochelle, France, April 1957	6	8.1–25.3	14.50	44.0	.45–1.0	.52	17.3	.11– .65	.26	13.0
Abattoir, Verdun, France, July 1957	5	3.1– 6.0	4.22	12.8	.10– .52	.27	9.0	.16– .50	.37	18.5
Piggery near Chinon, France, October 1957	4	1.1– 6.2	3.40	10.3	.06– .09	.07	2.3	.03– .07	.04	2.0
Farm near Orleans, France, July 1956	10	6.4–16.3	12.10	36.7						
Normal flies[a]			0.33			0.03			0.02	

[a] Average LD-50's given by Decker & Bruce (1952) for a strain of flies with normal susceptibility to DDT, lindane and dieldrin.

each. For example, a strain of flies estimated to show 50% mortality when dosed with 6.25 micrograms of DDT would be treated in all test series with dilutions in which droplets contained 1.56, 3.12, 6.25, 12.50 and 25 micrograms of the insecticide, respectively. After applications of the insecticide the flies were placed in 2-gallon glass animal jars, covered with stockinet and held at a temperature of 27 ± 1° C. for 24 hours. Food and moisture were provided by putting a cotton wad wetted with whole milk inside the jars and another wad wetted with water placed on the stockinet cover. After 24 hours, the LD-50 was selected as that concentration of insecticide causing the closest to 50% mortality. As controls jars of 50 flies were treated with droplets of plain acetone and the dead flies used by Abbott's correction formula (per cent living in control minus per cent living in test divided by per cent living in control equals correct per cent mortality) in selecting the LD-50. After the several generations of a strain had been tested the overall LD-50 was computed as the arithmetic mean of the individual LD-50's.

RESULTS AND DISCUSSION.—The range of LD-50's recorded, as well as the mean LD-50 for each strain, and its ratio to normal or susceptible flies as recorded by other workers are summarized in tables 1 and 2. There were no nonresistant laboratory strains of house flies available for rearing in parallel for comparison with strains studied, however it is of interest to make comparisons with susceptible strains reported by other workers. Decker & Bruce (1952) make the statement that five-to-ten-fold resistance is required for significance. On this basis, a comparison of the LD-50's of strains considered in table 1 with "their" nonresistant laboratory strain, which indicated LD-50's of 0.33 micrograms of DDT, 0.03 of lindane and 0.02 of dieldrin, indicates that all strains were resistant to DDT. The ratios with DDT were Heidelberg strain 71.0 times, La Rochelle 44.0×, Orleans 36.7×, Munich 29.7×, Frankfurt 16.8×, Dankenfeld 12.9×, Verdun 12.8×, Chinon 10.3× and Landstuhl 6.2×. There was a mean LD-50 range from 23.43 micrograms for the Heidelberg strain to 2.04 for the Landstuhl strain. Similarly, a mean LD-50 range with lindane of 0.52 micrograms for the LaRochelle strain to 0.07 for Chinon gives ratios of 17.3× for LaRochelle, Heidelberg 14.3×, Verdun 9.0×, Dankenfeld 5.7×, Munich 5.0×, Landstuhl 4.7×, Frankfurt 3.0× and Chinon 2.3×. Thus, the only strains significantly resistant to lindane, using Decker and Bruces' criteria, are the first five listed above. A mean LD-50 range with dieldrin of 0.66 micrograms for the Heidelberg strain to 0.04 for Chinon gives ratios of 33.0× for Heidelberg, Verdun 18.5×, LaRochelle 13.0×, Munich 10.0×, Dankenfeld 9.0×, Landstuhl 4.5×, Frankfurt 4.0×, and Chinon 2.0×. Thus, the only strains significantly resistant to dieldrin are the first five listed above. A comparison of results with malathion may be

Table 2.—Toxicity of malathion to eight house fly strains in Europe.

Source and Collection Date	No. of Test Series	Range of LD-50's	Mean of Individual LD-50's	Ratio of LD-50 to Susceptible Flies
Frankfurt Piggery, 1957	4	0.20–.30	0.24	0.9
Heidelberg Piggery, 1957	4	.31–.45	.36	1.3
Munich Piggery, 1957	3	.07–.25	.19	0.7
Landstuhl Piggery, 1957	4	.08–.65	.44	1.6
Dankenfeld Farm House, 1956	3	.16–.20	.17	0.6
La Rochelle City Dump, 1957	4	.45–.50	.47	1.7
Verdun Abattoir, 1957	3	.16–.25	.21	0.8
Chinon Piggery, 1957	3	.07–.23	.16	0.6
Susceptible flies[a]			.28	

[a] Average LD-50's given by Byers *et al.* (1956) for the more susceptible to malathion of four highly-susceptible strains studied in Japan.

made by using the finding of Byers *et al.* (1956) of 0.28 micrograms for LD-50 for the more susceptible of four highly susceptible strains studied in Japan. For malathion (table 2) there was a mean LD-50 range of 0.47 micrograms for the LaRochelle strain to 0.16 for Chinon. Comparing the individual mean LD-50's with Byers *et al.* 0.28 micrograms for susceptible flies, the ratios are 1.7× for LaRochelle, Landstuhl 1.6×, Heidelberg 1.3×, Frankfurt 0.9×, Verdun 0.8×, Munich 0.7×, Dankenfeld 0.6× and Chinon 0.6×. Again using Bruce and Deckers' criteria of five-to-ten-fold resistance for significance, it appears that none of the strains reported herein are resistant to malathion.

Although, a considerable degree of resistance to DDT, lindane and dieldrin is indicated in these studies, actual field experience to date shows that adequate control of house flies with the proper application of DDT and/or lindane is still possible in most areas of Germany and France. Malathion should prove an effective alternate insecticide when the requirement exists.

REFERENCES CITED

Byers, G. W., C. M. Wheeler and T. E. Blakeslee. 1956. A study of insecticide resistance in house flies of Japan and Okinawa. Jour. Econ. Ent. **49**: 556–7.

Decker, G. C., and W. N. Bruce. 1952. House fly resistance to chemicals. Amer. Jour. Trop. Med. Hyg. **1**: 395–403.

Tarshis, I. B. 1957. An Apparatus and Technique for the Continuous Anesthetization of Haematophagous Insects with Dry Ice. Mosquito News **7**: 82–86.

Trevan, J. W. 1922. An apparatus for measuring small quantities of liquids. Lancet **202**: 786.

Relation of Aphids to the Spread of Cucumber Mosaic Virus in Gladiolus[1]

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ABSTRACT

A survey was made of the aphid species occurring on gladiolus. Virtual absence of colonization on gladiolus and the presence of alates of at least 18 species led to the conclusion that cucumber mosaic virus (CMV) spread would be largely due to migrating aphids.

Transmission tests were made with a CMV type strain and a CMV isolated from gladiolus. Transmission was obtained with six species not previously recorded as CMV vectors. A literature survey revealed that negative reports of CMV transmission with certain aphid species were based largely on inadequate tests. The conclusion was reached that probably the majority of colonizing or migrating aphid species found in a CMV-susceptible herbaceous crop would be CMV vectors.

The aphid transmissibility of a CMV isolate from daphne was lost during a period of about 9 months or reduced to a level of efficiency not detectable by tests involving 1100 aphids (*Myzus persicae* (Sulz.)).

Cucumber mosaic virus[2] causes a white-break disease of gladiolus in Oregon (McWhorter 1957). This virus has long been known to be aphid-transmitted (Doolittle 1916, Jagger 1916). The investigations reported herein were made to determine the role of aphids present on gladiolus in the spread of cucumber mosaic virus. Important in this respect would be the aphid species which occur on gladiolus, their relationship to the gladiolus plant, and their ability to transmit the cucumber mosaic virus.

APHIDS ON GLADIOLUS.—Aphids were collected from samples of 500 plants in each of seven fields at widely separated points in the Willamette Valley area in 1957. Collections were usually made from plants 12 to 24 inches high. This was possible because of the planting of different sized corms and because the gladioli in a field usually were not all planted at one time. Samples were taken from each field at six different times. Aphids collected are enumerated in table 1.

Only 240 wingless aphids were found on the 21,000 plants examined, indicating that aphid populations of consequence in virus spread are not likely to be produced within a gladiolus field as is the case, *e.g.*, with virus spread in peas and potatoes. The largest number of aphids collected on a sample of 500 plants was 61. Most of these were *Aphis fabae* Scop. The average number was about six per 500 plants. Collections and identifications were made in the 1957 season only, but observations in 1956 and 1958 substantiate the lack of aphid development on gladiolus. In addition to scattered small groups or single aphids of the species listed in table 1, occasional small colonies of *Aphis fabae* can be found on the calyxes in late summer or early autumn. Only one plant heavily infested with aphids was found in 3 years. This aphid was identified as probably *Aphis helianthi* Monell by Miss Louise Russell. None of the surrounding plants were infested. *Macrosiphum solanifolii* (Ashm.) matured on gladiolus in the field but did not develop colonies. When placed on caged plants (var. Picardy) in the greenhouse, however, enormous numbers developed.

Alates of at least 18 species were found on gladiolus (table 1). Occurrence of alates of many species on gladiolus and lack of aphid colonization indicate that virus spread in gladiolus is due to migrating aphids.

The numbers of alate aphids of the various species collected on the plants do not necessarily reflect accu-

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[2] In this paper the term "cucumber mosaic virus(es)," when used in a general sense, refers to the concept of cucumber mosaic virus, including strains recognized by Hopkins. (1952).

Table 1.—Aphids collected on gladiolus in the Willamette Valley area from June through August, 1957.[a]

SPECIES	ALATES	APTERAE
Amphorophora sonchi (Oestl.)	6	0
Amphorophora sp.	0	1
Anuraphis bakeri (Cowen)	2	0
Anuraphis helichrysi (Kalt.)	3	0
Anuraphis spp.	4	0
Aphis fabae	112	171
Brevicoryne brassicae (L.)	2	0
Capitophorus braggi (Gillette)	1	0
Capitophorus spp.	2	0
Hyalopterus atriplicis (L.)	9	0
Kakimia spp.	7	0
Macrosiphoniella spp.	1	0
Macrosiphum dirhodum	6	0
M. granarium	44	5
M. pisi (Kalt.)	6	2
M. scoliopi Essig	1	0
M. solanifolii	42	26
Macrosiphum spp.	1	32
Myzus persicae	24	0
Myzus spp.	18	0
Rhopalosiphum fitchii	4	0
R. nymphaeae (L.)	1	0
Sipha agropyrella HRL	1	0
Undetermined	1	3
Total	297	240

[a] This table lists the aphids collected on 42 samples of 500 plants each. Miss Louise Russell determined about 50 of the alate specimens. The remainder of aphids were identified by K. G. Swenson.

rately the relative numbers which had actually been there. The behavior of aphids after arriving on an unsuitable host varies greatly between different species.[3] The length of time the aphids of a particular species tend to remain on the gladiolus plant undoubtedly influences the number collected. This factor might have introduced a considerable discrepancy between the results obtained by the sampling method used in this study and the numbers which had actually occurred on the plants.

Aphid trapping might have been used as an alternative to collecting the aphids on the plants. Suction traps (Johnson 1950), sticky traps (Broadbent *et al.* 1948, Kaloostian & Yeomans 1944), vane-type traps (Davis & Landis 1949) and water-filled yellow pans (Moericke 1951) have been used for trapping aphids. Dickson *et al.* 1956 presented data showing that different trapping methods resulted in different estimates of the relative numbers of flying aphids of two species. Heathcote (1957) found that of various types of traps only suction traps indicate the numbers of aphids per unit of air volume and are nonselective where different species are involved. Robertson & Klostermeyer (1958) showed that the relative numbers of alates of three species determined by collecting the apids from bean leaves differed from the relative numbers obtained in the same fields using water-filled yellow pans. Only suction traps, then, are likely to provide representative samples of the aphids flying over a field where several aphid species must be compared. Suction traps, unfortunately, require electrical power and are expensive, especially where a number of fields must be sampled and daily catches are not required. In addition, whether the numbers of different species which alight on a crop plant are proportional to the numbers of those species flying over the crop is still a moot point.

The principal objectives of these studies were to determine the source of aphids capable of spreading viruses in the gladiolus crop, *i.e.*, whether from outside or inside the field, and to learn if few or many species were involved. Both these factors influence considerably the control of virus spread and could be determined without refined sampling methods. Knowledge of the behavior of migrating aphids is still too fragmentary to have assumed *a priori* that aphid migrants alight at the same rate on the plants in any field across which they happen to be flying.

The foregoing discussion indicates that only limited significance can be ascribed to the relative numbers of alates of the various species listed in table 1. The relative importance of these species as possible vectors of cucumber mosaic virus is thus concomitantly difficult to judge. Importance as a vector is, of course, determined by efficiency of virus transmission, as well as by abundance.

TRANSMISSION TESTS.—Many aphid species have been reported able to transmit cucumber mosaic virus (CMV) (table 4) in the papers of Heinze 1939, 1950, 1951, 1952, 1957, Gigante 1936, Semal 1958, McLean 1941, McClintock & Smith 1918, Doncaster & Kassanis 1946, Magee 1930, Wellman 1934, Hoggan 1930, Hollings 1955, Govier 1957, Doolittle 1916, Brierley *et al.* 1953. There have also been numerous reports of tests in which certain species did not transmit CMV. Some of these same species have given positive results for other workers. We made further transmission tests for two reasons: (1) to determine the transmitting ability of some of the aphid species occurring on gladiolus, and (2) to help to explain the discrepancies in results of previous workers.

MATERIALS AND METHODS.—Three cucumber mosaic viruses were used in these tests. One virus was the type strain obtained in 1954 by J. A. Milbrath from the American Type Culture Collection where it was designated "Cucumber Mosaic Common Type Culture #10". Milbrath subsequently maintained this virus in *Nicotiana tabacum* × *N. glutinosa* hybrids or in dessicated tissue until April, 1957 when he provided the writers with a culture of this virus. It was subsequently maintained by aphid transfer from cucumber to cucumber. The second virus was isolated from naturally-infected gladiolus and subsequently maintained in cucumber by aphid transfer. The third virus was isolated from naturally-infected daphne in April of 1954 by Milbrath and Young who refer to it as D-17 in their 1956 paper. They subsequently maintained it by mechanical transfer to various plants and in desiccated tissue.

Cucumber (var. A & C) was used both as a virus source plant and as a test or indicator plant in all transmission tests. In the tests represented in table 2, aphids were starved for one-half hour or more and then transferred to the diseased plant for 5 minutes before transfer to healthy plants. In the tests represented in table 3, unstarved aphids fed on the diseased plant for 15 to 60 minutes before transfer to healthy plants. Aphids were left on the healthy plants for 1 hour or more after which the plants were fumigated with nicofume and returned to the greenhouse.

Tests were made in replicates of five plants for each species included in table 2. Five uninoculated check plants

[3] F. J. McNicholas. Unpublished data.

Table 2.—Transmission tests with CMV type strain and and CMV isolate from gladiolus.[a]

SPECIES	TYPE STRAIN[b]	GLADIOLUS ISOLATE
Amphorophora rhododendri	4/10	8/10
A. sonchi	9/10	6/10
Aphis cardui L.	7/10	4/10
A. fabae	7/110	4/110
Brevicoryne brassicae	1/20	5/20
Macrosiphum barri	0/10	3/10
M. dirhodum	0/20	0/20
M. granarium	0/20	0/20
M. pisi	7/10	4/10
M. rosae (L.)	9/10	9/10
M. solanifolii	30/70	32/70
Myzus circumflexus (Buckt.)	1/25	1/60
M. persicae	3/10	4/10
Rhopalosiphum fitchii	1/30	0/30

[a] Most of the data in this table were taken from the M.S. thesis of R. L. Nelson.

[b] Denominator, number plants exposed to aphids from diseased plants: numerator, number plants infected. Ten aphids per plant.

Table 3.—Transmission tests with CMV isolate from *Daphne odora*.

SPECIES	RESULTS[a]
Amphorophora rubitoxica Knowlton	1/29
A. sonchi	4/20
Anuraphis tulipae	0/20
Aphis fabae	0/40
A. gossypii	2/20
A. helianthi	0/20
Brevicoryne brassicae	0/40
Hyalopterus atriplicis	0/60
Macrosiphum granarium	0/20
M. pisi	6/20
M. rosae	6/40
M. solanifolii	2/40

[a] Denominator, number plants exposed to aphids from diseased plants; numerator, number plants infected. Twenty aphids per plant.

were placed on the greenhouse bench along with every five plants which had been exposed to virus inoculation by aphids. Thus a total of 775 check plants were used. None of these became infected with CMV, indicating the absence of accidental transmission in the greenhouse and the reliability of results even though only 1 of 30 inoculated plants was infected by a particular aphid species.

The writers are indebted to Miss Louise Russell for identifying the species, *Macrosiphum dirhodum* (Walker), *Amphorophora rhododendri* (Wilson), *Aphis helianthi*, and *Anuraphis tulipae* (Fonsc.). Miss Russell had on previous occasions determined some other species so that the writers were able to identify them in this study.

RESULTS.—Fourteen aphid species were tested for ability to transmit two cucumber mosaic viruses (table 2). *Macrosiphum dirhodum* and *M. granarium* (Kby.) did not transmit either virus. *Rhopalosiphum fitchii* (Sand.) did not transmit the CMV isolate from gladiolus and *Macrosiphum barri* Essig did not transmit the type strain. There was considerable variation in efficiency among those species which did transmit these viruses.

Transmission tests with the CMV isolate from daphne gave negative results with 6 of 12 species (table 3). These tests were made between August 29 and October 15, 1956. In April, 1957, desiccated leaves from tobacco plants infected with this virus were used for mechanical inoculation of cucumber plants. When symptoms appeared, attempts were made to inoculate another series of plants, using the aphid, *Myzus persicae*. None of these plants became diseased. Further transmission tests were made with *M. persicae* until 600 aphids had been used. Only negative results were obtained. All these aphids had been starved preceding short feeding periods on the diseased plant. Subsequently, from August 28, 1957 to January 18, 1958, comparative transmission tests were made with the daphne isolate and the type strain. The daphne isolate could be transmitted mechanically only, so virus source plants for the type strain were also inoculated mechanically for these tests. Aphids (*M. persicae*) were starved for at least one-half hour and then transferred to diseased plants for 5 minutes. Ten replicates were made, each consisting of five cucumber plants with 10 aphids per plant from each virus strain. Ten of 50 plants were infested with the type strain. No plants were infected with the daphne isolate.

Thus between August, 1956, when virus of the daphne isolate was obtained from J. A. Milbrath's stock culture and April, 1957, when it was again obtained, aphid transmissibility of the stock culture apparently declined to a level of efficiency below that detectable in these tests, or perhaps was lost. Hollings (1955) reported greatly diminished aphid transmissibility by the chrysanthemum aspermy virus which Govier (1957) considered a strain of CMV.

DISCUSSION.—Results presented in table 2 indicate that most aphid species found in gladiolus would be able to transmit CMV, if the aphid transmission of the type strain and the gladiolus isolate is typical of most CMV strains. Numerous reports have been made, however, of lack of transmission by some aphid species. Most of these same species have given positive results for other workers. Negative results have been reported even with *Myzus persicae* and *Aphis gossypii* Glover, which most workers have found to be relatively efficient CMV vectors. Examination of the negative reports shows that in nearly all cases the tests were not sufficiently extensive and no conclusions are warranted from the negative results obtained. In our transmission tests (table 2) the rate of transmission by certain species was so low that several hundred aphids were needed to detect it. This was particularly true of *Aphis fabae*. Simons (1957) found that three CMV strains varied in the efficiency with which they were transmitted by aphids. This indicates that more extensive tests would be needed for some strains or isolates than for others. Significance for field spread of such a low rate of transmission might be questioned were it not for the enormous numbers of aphids to which crops may be exposed. Dickson *et al.* (1956) estimated that as many as nearly a million aphids may fly to a single orange tree during the course of a year. Usually only a small number of aphids was found on a sample of 500 gladiolus plants. These samples, however, show only the number of aphids present at the time of sampling. The number of aphids occurring in a gladiolus field during a growing season would undoubtedly prove to be enormous if records were available showing all the aphids occurring on a unit of 500

Table 2.—Aphid species reported capable of transmitting CMV or strains thereof.[a]

SPECIES[b]	SOURCE
Amphorophora lactucae (L.)	Heinze 1950
A. viciae (Kalt.)	Heinze 1957
Aphis abbreviata Patch	Heinze 1939
A. cirsii-acanthoidis Scop.	Heinze 1957
A. craccae L.	Heinze 1950
A. fabae Scop.	Govier 1957
A. gossypii	Doolittle 1916
A. helichrysi Kalt.	Heinze 1950
A. mordwilkiana Dobz.	Heinze 1951
A. subterranea Walker	Heinze 1950
A. urticata Fabr.	Heinze 1950
Brevicoryne brassicae	Heinze 1950
Capitophorus ribis (L.)	Heinze 1952
Cavariella pastinacae (L.)	Gigante 1936
Cerosipha epilobiina Walker	Heinze 1957
Chaitophorus betulinus v. d. G.	Heinze 1957
Dactynotus cichoricola HRL	Semal 1958
Hyalopterus arundinis (Fabr.)	Heinze 1950
Macrosiphum obscurus (Koch)	Heinze 1950
M. pisi	McLean 1941
M. sanborni Gill.	Hollings 1955
M. solanifolii	McClintock & Smith 1918
M. tanaceti (L.)	Heinze 1950
Metopeurum fuscoviride Stroyan	Heinze 1957
Metopolophium occidentale HRL	Heinze 1957
Myzus ascalonicus Donc.	Doncaster & Kassanis 1946
M. circumflexus	Hoggan 1930
M. ligustri (Mosley)	Heinze 1952
M. ornatus Laing	Heinze 1939
M. persicae	McClintock & Smith 1918
M. solani (Kalt.)	Hoggan 1930
Nasonovia ribicola (Kalt.)	Heinze 1950
Pentalonia nigronervosa Coq.	Magee 1930
Rhopalosiphoninus latysiphon (David.)	Heinze 1950
Rhopalosiphum junackianun(Karsch)	Heinze 1952
R. maidis (Fitch)	Wellman 1934
R. nymphaeae	Heinze 1952
R. rufomaculatum (Wilson)	Brierley, *et al.* 1953
R. tanacetina (Walk.)	Heinze 1950
Rungsia maydis Pass.	Heinze 1957

[a] This is not a complete list because the identity of a number of probable CMV strains is not certain.

[b] The names used in this table are those which Dickson (1955) states are preferred by American entomologists, unless the names were not included in Dickson's paper. These are frequently different from those used in the literature cited.

plants during the season and this was expanded by a factor indicating the total of such units in the field.

Lack of transmission by *Macrosiphum granarium* and *M. dirhodum* is difficult to evaluate. Perhaps they cannot transmit CMV. A gradation is observable, however, from the relatively efficient species to the least efficient species (table 2). Possibly *M. granarium* and *M. dirhodum* transmit CMV at such a low rate that a more extensive test would have been necessary to detect this ability. Their transmission rates could be lower than one in 200 and still be well above the average of one in 5600 given for *Aphis gossypii* with the tristeza virus (Dickson *et al.* 1956). *Macrosiphum granarium* is very common in gladiolus fields and, even though an inefficient vector, could be of importance in CMV field spread, as is *Aphis gossypii* in the field spread of the tristeza virus.

In summary, any cucumber mosaic virus which presents a field problem in an herbaceous crop probably will be transmissible by the majority of migrating or colonizing aphid species found on that crop. This view is supported by the results presented herein from transmission tests with two CMV strains, by the large number of species others have found capable of CMV transmission (table 4), and by the fact that most reports of negative results were based on transmission tests insufficiently extensive to detect a transmission rate as low as may occur with some species capable of CMV transmission.

REFERENCES CITED

Brierley, P., F. F. Smith, and S. P. Doolittle. 1953. Experiments with tomato aspermy virus from chrysanthemum. (Abstract) Phytopath. **43:** 404.

Broadbent, L., J. P. Doncaster, R. Hull, and M. A. Watson. 1948. Equipment used for trapping and identifying alate aphids. Proc. Roy. Ent. Soc. Lond. **23:** 57–8.

Davis, E. W., and B. J. Landis. 1949. An improved trap for collecting aphids. U. S. Dept. Agric. Bur. Ent. and Plant Quar. **ET-278.**

Dickson, R. C. 1955. A working list of the names of aphid vectors. Plant Dis. Reporter **39:** 445–52.

Dickson, R. C., M. McD. Johnson, R. A. Flock, and E. F. Laird, Jr. 1956. Flying aphid populations in southern California citrus groves and their relation to the transmission of the tristeza virus. Phytopath. **46:** 204–10.

Doncaster, J. P., and B. Kassanis. 1946. The shallot aphis, *Myzus ascalonicus* Doncaster, and its behavior as a vector of plant viruses. Ann. Appl. Biol. **33:** 66–8.

Doolittle, S. P. 1916. A new infectious mosaic disease of cucumber. Phytopath. **6:** 145–7.

Gigante, R. 1936. Il mosaico del Sedano. Boll. Staz. Patol. Veg. Roma, N. S., **16:** 99–114. (Abstracted in Rev. Appl. Mycol. **16:** 227–8. 1937).

Govier, D. A. 1957. The properties of tomato aspermy virus and its relationship with cucumber mosaic virus. Ann. Appl. Biol. **45:** 62–73.

Heathcote, G. D. 1957. The comparison of yellow cylindrical, flat and water traps, and of Johnson suction traps, for sampling aphids. Ann. Appl. Biol. **45:** 133–9.

Heinze, K. 1939. Übertragung und Überwinterung des Lupinebräune-Virus. Mitteil. Biol. ZentAnst. Berl. **59:** 84–6.

Heinze, K. 1950. Zur Übertragung pflanzlicher Viruskrankheiten durch Blättlause. Nachrichtenbl. deutsch. Pflanzenschutzdienst. (Braunschweig) **2:** 49–53.

Heinze, K. 1951. Die Übertrager pflanzlicher Viruskrankheiten. Mitteil. Biol. ZentAnst. Berl. **71:** 1–126.

Heinze, K. 1952. Virusübertragungsversuche mit Blattläusen auf Dahlien, Gurken, Zwiebeln, Wasserüben und einigen anderen Pflanzen. Z. Pflkrankh. **59:** 3–13.

Heinze, K. 1957. Weitere Versuche zur Übertragung von phytopathogenen Viren mit Blättlausen. Nachrichtenbl. deutsch. Pflanzenschutzdienst. (Braunschweig) **9:** 22–5.

Hoggan, I. A. 1930. Studies on aphid transmission of plant viruses. Jour. Bact. **19:** 21–2.

Hollings, M. 1955. Investigations of chrysanthemum viruses. I. Aspermy flower distortion. Ann. Appl. Biol. **43:** 86–102.

Hopkins, J. C. F. 1952. Common names of virus diseases used in the Review of Applied Mycology. Rev. Appl. Mycol. **35,** Suppl., 78 pp.

Jagger, I. C. 1916. Experiments with the cucumber mosaic disease. Phytopath. **6:** 148–51.

Johnson, C. G. 1950. The comparison of suction trap, sticky trap and tow net for the quantitative sampling of small airborne insects. Ann. Appl. Biol. **37:** 268–85.

Kaloostian, G. H., and M. S. Yeomans. 1944. A sticky board

trap used in scouting for pear psylla. U. S. Dept. Agric. Bur. Ent. and Plant Quar. ET-220.

Magee, C. J. 1930. A new virus disease of bananas. Agric. Gaz. N. South Wales **41:** 929.

McClintock, J. A., and L. B. Smith. 1918. True nature of spinach-blight and relation of insects to its transmission. Jour. Agric. Res. **14:** 1–60.

McLean, D. M. 1941. Studies on mosaic of cowpeas, *Vigna sinensis*. Phytopath. **31:** 420–30.

McWhorter, F. P. 1957. A localized occurrence of cucumber mosaic virus in gladiolus. Plant Dis. Reporter **41:** 141–2.

Milbrath, J. A., and R. A. Young. 1956. Cucumber mosaic virus and alfalfa mosaic virus isolated from *Daphne odora*. Plant Dis. Reporter **50:** 279–83.

Moericke, V. 1951. Eine farbfalle zur Kontrolle des Fluges von Blättlausen, insbesondere der Pfirsichblattlaus, *Myzodes persicae* (Sulz.). Nachrichtenbl. deutsch. Pflanzenschutzdienst. (Braunschweig) **3:** 23–4.

Robertson, R. S., Jr., and E. C. Klostermeyer. 1958. Aphid populations on field beans in Washington. Jour. Econ. Ent. **51:** 178–81.

Semal, J. 1958. Virus transmission by *Dactynotus cichoricola* H.R.L., a new aphid on Chicory. Nature **181:** 721.

Simons, J. N. 1957. Three strains of cucumber mosaic virus affecting bell pepper in the Everglades area of South Florida. Phytopath. **47:** 145–50.

Wellman, F. L. 1934. A disease of banana, markedly similar to bunchy top, produced by celery virus I in U.S.A. Phytopath. **24:** 1032–4.

Comparison of Two Systemic Insecticides and Dates of Application for Cattle Grub Control in the Everglades[1]

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ABSTRACT

When applied in May, June, July, or August, a single dermal spray of Bayer 21/199 (Co-ral) was significantly more effective than an oral drench of Dow ET-57 (Trolene) in reducing the numbers of common cattle grubs, *Hypoderma lineatum* (DeVill.), that later appeared in the backs of Everglades cattle. Dow ET-57 was significantly more effective than Bayer 21/199 when each was applied in September. The June application of Dow ET-57 was significantly less effective than those made in May, July, August, or September.

Until recent years the common cattle grub, *Hypoderma lineatum* (DeVill.), was not a problem in the Everglades. Genung (1954) reported an unusually heavy population of this insect during the winter of 1953–54. This was the first published account of the common cattle grub in the area. The incidence and degree of cattle grub infestation among Everglades cattle seem to have increased gradually since that time. Although the number of grubs observed in the backs of cattle is still much lower than that reported in other areas of the United States, the pest appears to be potentially of much greater importance than it is at present. In the Everglades, animals with grubs encysted in the back have been noticed in every month except June, although much less frequently during the late spring, summer, and early fall. This seems to indicate that there is a possibility of the common cattle grub becoming a year round pest in the Everglades with subsequent difficulties in controlling it.

For many years the standard recommendation for cattle grub control was to apply rotenone to the backs of infested animals. This was effective only against those grubs that had already cut a hole through the skin of the animal.

Crenshaw (1956) reported that grubs could be killed before reaching the back by an oral application of Dow ET-57 (Trolene).[4] Preliminary experiments on ranches in the Everglades indicated that Dow ET-57 was effective in reducing the number of grubs that reached the back (Harris *et al.* 1957). Single applications during July, August, or September were more effective than an October treatment.

Brundrett *et al.* (1957) reported that young grubs could be destroyed before breaking through the skin of the back with a single application of Bayer 21/199 (Co-ral) spray. Smith & Richards (1954) had previously reported that an external wash with Bayer 21/199 was effective against grubs that had encysted in the back. Roth & Eddy (1955) found that a spray was more effective than a wash.

Brundrett *et al.* (1957) compared Dow ET-57 and Bayer 21/199 in dermal sprays and found Dow ET-57 was ineffective when applied dermally. Burns & Newsom (1958) studied dermal applications of Bayer 21/199 and oral applications of Dow ET-57. Each material was applied on several dates from June through August and Bayer 21/199 was used at three concentrations. They presented no conclusions concerning comparisons among the insecticides, the dates of application, or the different rates of Bayer 21/199 applied.

The purpose of the experiment reported herein was to compare the relative efficacy of Dow ET-57 and Bayer 21/199 and to estimate the best time to make a single application of either material. It seems desirable to destroy the grubs as soon as possible after they have entered the body and yet apply the treatment late enough to minimize or obviate reinfestation by ovipositing females after the effectiveness of the chemical has dissipated.

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[4] After this paper was prepared the common name, ronnel, was adopted for *O,O*-dimethyl *O*-(2,4,5-trichlorophenyl) phosphorothioate which has previously been called Dow ET-57, Korlan, or Trolene.

PROCEDURE.—On each of five application dates 10 animals were treated with Dow ET-57 and another 10 with Bayer 21/199, so that 50 animals were treated with each insecticide. The treatment dates were May 6, June 5, July 8, August 22, and September 16, 1957. Twenty-five animals were not treated and were used to estimate the cattle grub population level. Some animals were lost during the experiment so that each treatment contained nine animals with the exception of each of the August treatments which contained 10 and the September Bayer 21/199 treatment which contained only eight animals. Loss of animals from the experiment was in no way connected with the systemic insecticide treatments.

Aberdeen Angus, Devon, Brahman, Brahman-Devon, and Brahman-Angus calves were assigned to treatments randomly within each breed and sex. Five steers and five heifers were treated with each insecticide on every application date. At the initiation of the experiment (May 6), the animals were 7 to 9 months old. They were weaned in early June.

Bayer 21/199 was applied as a 2.5% spray prepared from a 25% wettable powder and water. A trombone type hand sprayer[5] was used to apply 1 pint of spray along the back of each animal to give 11.25 grams of actual toxicant per animal. The body hair was short at each application date and the spray readily penetrated through the hair to wet the skin. Dow ET-57 was applied as an oral drench that contained 10 milliliters of a 50% emulsion concentrate in water to make 1 ounce of liquid. The drench was applied at the rate of 1 ounce to each 100 pounds of animal, resulting in a dosage of 5 grams of actual Dow ET-57 per 100 pounds. The average weight per animal at the time of treatment was 360 pounds for animals treated May 6 and 560 pounds for the animals that were treated September 16.

From October 11, 1957 until April 9, 1958 each animal was examined at 2-week intervals for a total of 14 observations. The number of cattle grubs per animal was counted by feeling for the resulting bumps under the hide. This method gave no figure for the accumulative number of grubs in any one animal, but only the number of grubs present in the back at the time of examination.

The number of grubs observed on each animal on each observation date was transformed to

$$\sqrt{\text{number}+0.5}\times 100$$

before conducting the analyses of variance (Snedecor 1946). Variances were analyzed for each observation date and also for the totals of the observation dates to compare the effects of the chemicals and dates of application over the entire observation period. The untreated animals were not included in the analyses as it was obvious that in each case the insecticide treatment greatly reduced the number of cattle grubs found among the cattle.

RESULTS.—Cattle were not examined closely for the presence of encysted grubs at the time of applying the systemic insecticides, but one of the animals treated in August was noticed to have five young grubs under the hide of the back. Another animal that had not yet been treated had two grubs. Five of the animals that were treated September 16 had two to five grubs each.

The peak of cattle grub infestation among the 25 untreated animals occurred January 15 when there was an average of 18.1 grubs per animal (fig. 1). The peak of infestation for the animals treated with Dow ET-57 occurred February 12 when there was an average of 0.87 grubs per animal over all treatment dates. The infestation among the animals treated with Bayer 21/199 was never more than 0.11 grubs per animal and there was no true peak. The number of grubs found among animals treated with Bayer 21/199 was significantly less than that among Dow ET-57-treated cattle on January 1, 1958 and on each date from January 29 through the last observation April 9, 1958.

Among animals that were treated in May, June, July or August with Dow ET-57, the highest numbers of grubs appeared in the back about 28 to 42 days after the peak of infestation among untreated animals (fig. 2). Among the animals treated with Bayer 21/199, there was no apparent peak of infestation for any of the treatment dates. Animals that were treated with Bayer 21/199 or Dow ET-57 in September had a larger number of grubs in the back on October 11 than later in the season.

The seasonal average number of cattle grubs encysted in the backs was much larger for those cattle treated with Dow ET-57 than for those treated with Bayer 21/199 for each treatment date except September (fig. 3). When treatments were made in September, Dow ET-57 gave significantly better cattle grub control than Bayer 21/199.

[5] Little Giant—Sprayers and Nozzles, Inc., St. Petersburg, Florida.

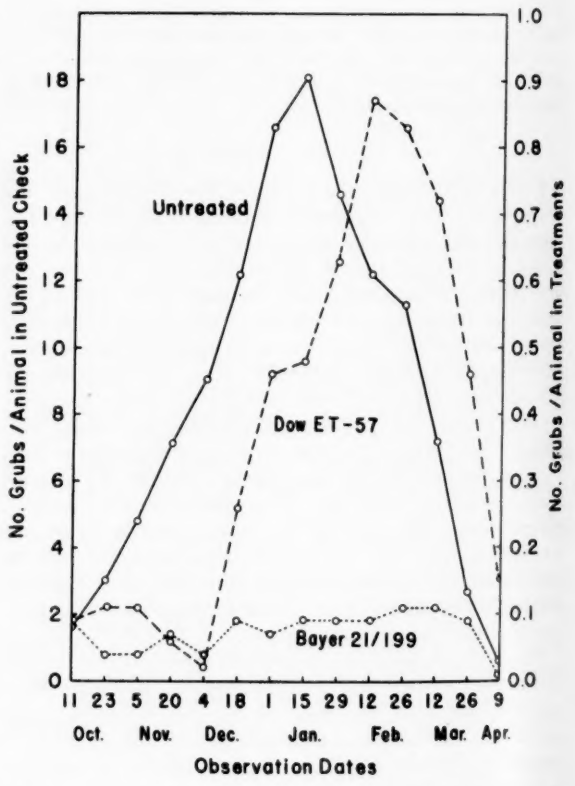

FIG. 1.—Comparison of untreated check with treatments with Dow ET-57, and Bayer 21/199 against the common cattle grub on each of 14 observation dates.

The number of cattle grubs appearing in the backs of animals treated in June with Dow ET-57 was significantly larger than that for any other treatment. This was true on the majority of the observation dates and also for the seasonal average. The May application of Bayer 21/199 was significantly more effective than that in June or September, and the July application was significantly better than that made in September. Since the average number of grubs for the September treatment (the least effective one) with Bayer 21/199 was only 0.14 grub per animal when averaged for the 14 observations dates, it is doubtful that the differences among the Bayer 21/199 application dates were realistic from a commercial point of view. The only Dow ET-57-treatment that compared favorably with the Bayer 21/199 treatments was the one made in September. Treatment with Dow ET-57 in September was significantly better than the treatments made with that material on any other date. The May treatment was significantly better than the one made in July. All other Dow ET-57 treatments were significantly better than the one made in June.

CONCLUSIONS.—In general Dow ET-57 was much less effective than Bayer 21/199 in reducing the incidence of cattle grubs in the backs of cattle in the Everglades. The peak of infestation among the animals receiving the treatments with Dow ET-57, with the exception of the September treatment, was about 28 to 42 days later than that among the untreated cattle. This might imply that Dow ET-57 either retarded the development of some of the grubs not killed within the animal's body or that reinfestation occurred after the effectiveness of the chemical had diminished. The fact that the September application was by far the more effective Dow ET-57 treatment might support the latter, but such a conclusion might indirectly imply that Bayer 21/199 was effective for several months and this would not seem likely. The reversal of the relative efficacy of Dow ET-57 and Bayer 21/199 in the September treatments could have been caused by the two chemicals being influenced differentially by such factors as the age or location of grubs, physiology of grub or host, or environmental influences at or near the time of treatment. These phenomena might also be responsible for the variability in effectiveness of Dow ET-57 among the application dates.

Bayer 21/199 or Dow ET-57 applied as early as May was effective in controlling cattle grubs before they reached the backs of cattle. It seems desirable to kill the grubs as soon as possible after they have entered animal tissue, but also to apply the chemical late enough to prevent reinfestation after the chemical has ceased to be active within the body. In another year a high incidence of reinfestation might occur after the effectiveness of an early treatment has disappeared.

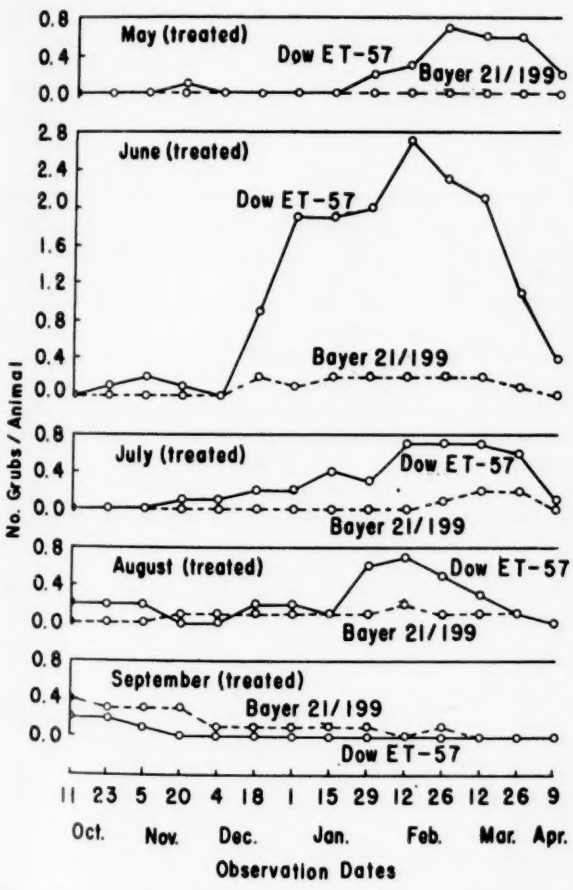

FIG. 2.—Comparison of effectiveness of Dow ET-57 and Bayer 21/199 against the common cattle grub by application dates on each of 14 observation dates.

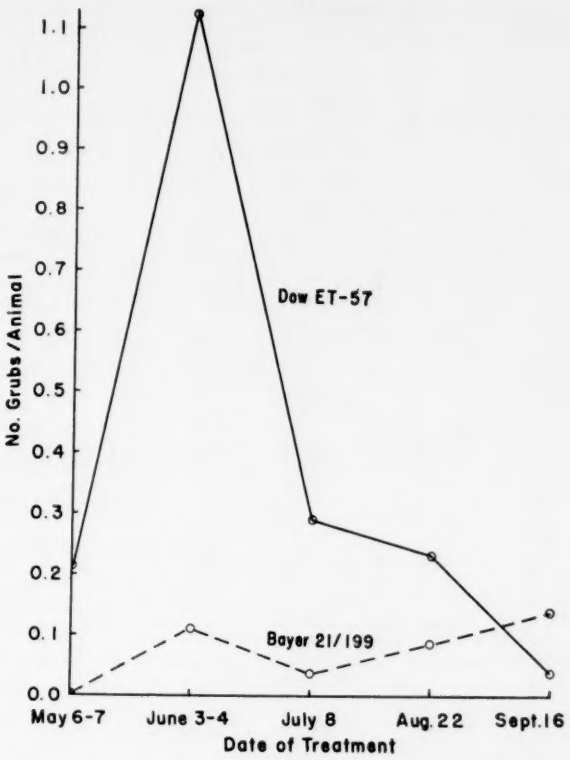

FIG. 3.—Comparison of seasonal effectiveness of Dow ET-57 and Bayer 21/199 against the common cattle grub. (Five application dates.)

REFERENCES CITED

Brundrett, H. M., W. S. McGregor, and R. C. Bushland. 1957. Systemic cattle grub control. Agric. Chemicals **12**(6): 36–37.

Burns, Edward C., and L. D. Newson. 1958. Cattle grub control with systemic insecticides. Louisiana Agric. **1**(3): 10–11.

Crenshaw, G. L. 1956. Dow-ET-57 a systemic animal insecticide. Down to Earth **12**(3): 4–7.

Genung, W. G. 1954. Biology and control of insects and arachnids affecting vegetable crops in the Everglades region. Insect pest Survey. Florida Agric. Expt. Sta. Ann. Rept. for the fiscal year ending June 30, **1954**: 207.

Harris, E. D., Jr., W. G. Genung, and H. L. Chapman, Jr. 1957. Cattle grub investigations. Florida Agric. Expt. Sta. Ann. Rept. for the fiscal year ending June 30, **1957**: 272–3.

Roth, A. R., and Gaines W. Eddy. 1955. Tests with some phosphorus compounds against cattle grubs. Jour. Econ. Ent. **48**(2): 201–2.

Smith, Charles L., and Rowland Richards. 1954. New insecticides for control of the cattle grub. Jour. Econ. Ent. **47**(4): 712–3.

Snedecor, George W. 1946. Statistical Methods. Fourth Edition. Iowa State College Press, Ames, Iowa. 485 pp.

The Effect of Several Insecticides on the Total Arthropod Population in Alfalfa[1]

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ABSTRACT

Sprays containing parathion, malathion, demeton, endrin or toxaphene applied to alfalfa caused marked reductions of the total arthropod populations. Reductions were greater for the phytophagous species as a group than for the entomophagous species. The toxic effects of some of the insecticides to certain insect predators created favorable conditions for their prey which became more numerous later on in the sprayed plots than in the untreated checks. The specificity of certain of the insecticides caused profound changes in the components of the populations. The residual effects of all of the above were quite limited due to migration into or between plots. At the dosages used, namely 3 pounds toxaphene, ½ pound malathion, and ¼ pound each of parathion, endrin or demeton,—toxaphene was generally less effective than the others. Parathion was the most toxic to some of the beneficial species and endrin was the least toxic.

Considerable work has been done in the past few years on the effects of insecticides on beneficial insects, but so far as is known, no work has been published on the effects of insecticides on the total arthropod population in alfalfa. This paper reports results of a two-year study, 1954 and 1955, on the effect of insecticide spray applications on the total arthropod population in alfalfa. Gaines (1954), van den Bosch *et al.* (1956), Ahmen (1954) and Wene (1953, 1954), studied the effects of a number of compounds on the beneficial species present in various crops including alfalfa.

The data reported in this paper are based on a study of the effects of toxaphene, parathion, endrin, and demeton (Systox) applied to small replicated plots, each 1/40 acre in size, and in one large scale field test where malathion was the insecticide used. The untreated checks in the small plot tests were replicated the same as the sprayed plots but in the large scale test there were no replications and the check was a ⅛-acre plot of alfalfa in the same field. The insecticides were applied to the small plots at the rate of 40 gallons per acre April 26 and June 10, 1954; and July 8, 1955, at the following amounts of actual toxicants per acre: toxaphene, 3 pounds, parathion, endrin, and demeton, ¼-pound each. In the large scale test, malathion was applied at the rate of ½-pound in 8 gallons of spray per acre, May 3, 1955.

Populations were determined by sweeping with an insect net at the rate of 25 to 50 sweeps per plot or sampling area, depending upon a pilot sample estimate of the numbers of arthropods present. In the small plot tests each plot replicated was sampled; in the large scale field test, there were five sampling areas staked out in the sprayed part of the field and five in the check area. Samples were taken before treatment, immediately after and subsequently at various intervals, usually weekly, weather permitting. The procedure used has been reported by Fenton & Howell (1957). Determinations were made by specialists.[2]

Due to the enormous numbers of insects and spiders collected it is impossible to present all of the data by species, nor is this necessary. However, it is well to point out that a total of 396 species of insects, 15 species of spiders, and several species of mites were collected. Most of these were not taken in sufficient numbers to be included in a statistical analysis of the data. Instead, with the exceptions noted later in this report, they were grouped together for one part of the study, into four

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Table 1.—Effect of four insecticides applied April 26 to alfalfa on the populations of the most common arthropods, 1954.

	Number Collected per 100 Sweeps										
	Untreated			Toxaphene		Parathion		Demeton		Endrin	
	April		June	April	June	April	June	April	June	April	June
Arthropods[a]	24	28	9	28	9	28	9	28	9	28	9
Hippodamis convergens, A	906	79	1	26	2	19	10	53	11	46	1
H. convergens, L	238	54	16	53	15	19	17	27	18	53	12
Lygus lineolaris, A	220	15	38	21	17	24	28	22	32	7	11
L. lineolaris, N	78	16	89	7	32	4	55	12	31	0	18
Nabis alternatus, A	62	10	5	4	4	1	11	8	9	6	2
N. alternatus, N	0	24	43	10	19	4	19	26	28	24	30
Orius insidiosus, A	1	0	10	1	16	1	49	0	37	0	13
O. insidiosus, N	0	0	149	0	110	0	169	0	126	0	127
Nysius raphanus	672	35	0	24	0	30	1	68	0	28	0
Aphidius sp.	454	1	11	9	8	9	14	3	24	4	2
Macrosiphum pisi	8,296	50	290	52	379	91	553	56	438	44	114
Aceratagallia uhleri, A	338	170	62	85	32	57	8	36	64	35	31
A. uhleri, N	2,880	1,549	67	706	116	382	69	116	47	196	107
Chrysopa plorabunda, A	4	4	0	1	0	2	0	1	1	2	0
C. plorabunda, L	108	73	4	48	5	24	3	85	6	54	1
Frankliniella occidentalis	0	2	229	4	220	3	340	5	295	1	196
Araneida sp.	58	38	55	35	70	37	82	43	84	18	48
Other species	498	148	150	161	309	139	347	139	365	138	255
Totals	14,813	2,268	1,219	1,247	1,354	846	1,775	700	1,616	655	968

[a] A, denotes adults; L, larvae; N, nymphs.

classes; phytophagous, entomophagous, pollen and nectar feeders, and scavengers. The first two classes comprised most of the species collected and it is for these that the data have been compiled and analyzed.

TESTS IN 1954.—The effects of the four insecticides on the total spider-insect population are shown in tables 1 and 2. The first application of the insecticides caused a greater reduction in the plant feeders April 28 than it did in the entomophagous species. By June 9, however, there was little difference between the populations of these groups and the checks indicating that a recovery had taken place (table 1).

The second sprays were applied June 10 and their effects upon the arthropod populations June 14 and 29 are shown in table 2. When these data were analyzed for the entomophagous totals they showed that June 14 reductions were lower than in the checks with the least differences shown in the toxaphene plots and the least reductions and therefore greatest differences in the demeton plots. For the phytophagous species only parathion and demeton had caused greater reductions than in the checks. June 29, toxaphene and demeton had caused a greater reduction in the total entomophagous species than the checks, whereas parathion and endrin reductions were less than in the checks.

During the course of the experiment, the alfalfa leafhopper, *Aceratagallia uhleri* Van D., was by far the most common species, comprising more than 90% of the total population during the first test. Therefore, the effects of the several insecticides on this species determined to a large extent the degree of reduction of the total arthropod population. The pea aphid, *Macrosiphum pisi* (Harris),

Table 2.—Effect of four insecticides applied June 10 to alfalfa on the populations of the most common arthropods, 1954.

	Number Collected per 125 Sweeps on Dates[a] Shown (June)														
	Untreated			Toxaphene			Parathion			Demeton			Endrin		
Arthropods and Stage of Development	9	14	29	9	14	29	9	14	29	9	14	29	9	14	29
Hippodamia convergens, A	1	7	2	2	7	0	10	5	1	11	4	2	1	6	2
H. convergens, L	16	3	0	15	3	0	17	3	0	18	0	1	12	0	0
Lygus lineolaris, A	38	6	0	17	5	1	28	15	0	32	8	0	11	8	2
L. lineolaris, N	89	18	0	32	2	0	55	1	2	31	5	0	18	0	2
Nabis alternatus, A	5	0	1	4	1	1	11	0	0	9	2	0	2	3	0
N. alternatus, N	43	22	0	19	14	0	19	6	1	28	10	2	30	19	1
Orius insidiosus, A	10	11	1	16	9	2	49	25	0	37	24	1	13	10	13
O. insidiosus, N	149	12	4	110	3	6	169	9	12	126	19	16	127	19	23
Aphidius sp.	11	4	0	8	0	0	14	4	5	24	4	1	2	3	0
Macrosiphum pisi	290	8	0	379	6	0	553	10	1	438	16	4	114	4	0
Aceratagallia uhleri, A	62	104	645	32	57	869	8	5	224	64	33	440	31	50	698
A. uhleri, N	67	149	301	116	219	273	69	9	35	47	43	177	107	112	148
Empoasca fabae, A	12	13	6	22	9	7	31	6	6	33	8	6	5	6	6
E. fabae, N	?	3	0	0	2	3	3	1	3	3	1	1	4	0	5
Spissistilus festinus	0	4	16	2	7	40	1	3	46	0	5	64	0	4	17
Frankliniella occidentalis	229	50	20	220	47	10	340	64	25	295	55	67	196	66	56
Araneida	55	122	180	70	133	354	82	242	427	84	265	531	48	144	305
Other species	142	201	217	290	175	303	316	205	413	336	231	478	247	168	259
Totals	1,219	737	1,393	1,354	699	1,869	1,775	613	1,201	1,616	733	1,791	968	622	1,537

[a] The temperature was 81, 84, and 81° F., respectively, and the wind velocity was 4, 3, and 0 m.p.h., respectively, at the time the collections were made.

Table 3.—Effect of malathion applied May 3 to alfalfa on the populations of the most common arthropods, 1955.

Arthropods and Stage of Development	Number Collected per 125 Sweeps on Dates Shown								
	May 3	May 10		May 17		May 24		May 31	
	Check	Check	Treated	Check	Treated	Check	Treated	Check	Treated
Hippodamis convergens, A	50	223	77	48	32	33	24	14	19
H. convergens, L	46	46	3	1	0	1	0	0	0
Hylemya cilicrura	3	10	11	2	5	6	7	6	4
Syneches sp.	41	25	92	70	140	46	33	62	33
Thaumatomya glabra	2	13	52	10	25	60	21	15	29
Lygus lineolaris, A	174	78	18	46	17	37	16	23	25
L. lineolaris, N	105	3	0	17	7	27	3	19	3
Nabis alternatus, A	7	21	11	15	20	11	12	7	2
N. alternatus, N	63	63	2	0	1	3	0	1	0
Orius insidiosus, A	42	42	125	94	138	228	111	220	132
O. insidiosus, N	4	15	1	3	2	4	10	8	11
Macrosiphum pisi	15	22	39	7	37	18	63	27	116
Theriophis maculata	18,948	116	389	49	160	7	25	11	29
Aceratagallia uhleri, A	7	253	9	53	4	98	19	14	6
A. uhleri, N	0	356	1	73	7	57	0	10	2
Empoasca fabae	0	2	3	27	23	164	181	60	53
Macrosteles fascifrons	0	36	17	115	154	129	94	4	0
Chrysopa plorabunda, A	71	48	35	13	3	1	4	3	4
C. plorabunda, L	20	20	5	1	3	2	2	2	0
Araneida	50	90	99	42	73	68	52	31	18
Other species	390	564	558	566	662	1,493	1,327	505	462
Totals	20,038	2,046	2,547	1,252	1,513	2,493	2,004	1,042	948
Temperature ° F.	79	83.5		95		79		84	
Wind, m. p. h.	3	0		4.5		0		4	

and three of its most important enemies namely, *Hippodamia convergens* G.-M., *Chrysopa plorabunda* Fitch, and *Aphidius* sp., reached their peak of abundance prior to the first spray application. As will be shown later, the toxic effects of parathion on the lady beetle and to a lesser extent that of demeton and toxaphene, created favorable conditions for the multiplication of *M. pisi*.

Tests in 1955.—Table 3 shows the effects of the malathion spray on the arthropods present in the large scale test. The spotted alfalfa aphid (*Therioaphis maculata* (Buckton)) reached the peak of its abundance on the date of the spraying. The first postspraying count showed that remarkable reduction had taken place in both the sprayed and check plots. This situation was very similar to that in 1954 when the first spray application was made to control the pea aphid except that in the former year the pea aphid population had been going down steadily for some time before spraying. The reductions in the total plant insect feeding populations in both check and sprayed plots found May 10, seven days after treatment, were 95 and 97%, so were not significantly different. There continued to be very little difference in the total populations of phytophagous species up to and including May 31. On the other hand by May 10, increases were found in the entomophagus populations in the checks whereas in the sprayed alfalfa on this date only a slight increase was found. From this date on, reductions were recorded except for the checks May 24. These reductions were much lower for the entomophagous populations for the four dates than for the phytophagous populations.

The effects of the four insecticides, applied to the small plots, on the total populations of phytophagous species are shown in table 4. July 8 there was very little difference in per cent reductions caused by demeton and parathion. Endrin and toxaphene were less effective. July 15, increases had taken place in all plots, were greatest in the checks and toxaphene plots, with the smallest increase shown in the demeton plots.

For the phytophagous species parathion and demeton were most effective, endrin somewhat less so and toxaphene least effective, but all materials caused reductions over the checks. By July 15 the total population of phytophagous species, as listed in table 4, had increased by 125.6% in the checks. The increase was only 2.3% in the toxaphene plots and decreases were recorded for the other materials—21% for the parathion and endrin plots and 54.6% for the demeton plots. In these tests the spider population was not included in the calculations.

Effects of All Insecticides on Certain Species.—When it was possible to identify a species, and it was sufficiently numerous, the effects of the insecticides on it were evaluated by population changes. Here, it must be pointed out that migration into or out of the plots, the effects of unfavorable weather conditions and the interaction between a host and its natural enemies all cause population changes. Thus the best chance of determining the effects of insecticides on the species present came within a few days after the plots had been treated.

Hippodamia convergans: All insecticides reduced adult populations over the checks, parathion causing the greatest reduction. Demeton and endrin were less toxic than either parathion or toxaphene. No effects were observed on the larval populations.

Collops quadrimaculatus (Fab.): All materials reduced populations when this species was present in sufficient numbers to analyze the data.

Melanoplus bilituratus (Walker): Because of the strong flight powers of the adults, only data on the nymphs were

Table 4.—Effect of four insecticides applied July 6 to alfalfa on the populations of the most common arthropods, 1955.

Arthropods and Stage of Development	Number Collected per 125 Sweeps on Dates[a] Shown (July)														
	Untreated			Toxaphene			Parathion			Demeton			Endrin		
	6	8	15	6	8	15	6	8	15	6	8	15	6	8	15
Hippodamia convergens, A	8	13	19	15	3	14	8	1	1	20	0	1	10	1	2
H. convergens, L	9	6	49	12	7	34	3	4	1	7	0	1	9	4	3
Collops quadrimaculatus	0	1	45	0	1	21	0	0	22	0	0	15	0	0	19
Acrididae, N	13	17	28	13	2	8	17	1	29	15	1	16	8	0	1
Lygus lineolaris, A	17	10	13	34	2	13	48	0	19	39	1	9	33	1	10
L. lineolaris, N	11	7	24	14	2	1	14	1	23	29	0	10	14	1	6
Nabis alternatus, A	8	9	8	7	5	5	5	0	3	6	1	1	5	3	0
N. alternatus, N	3	2	4	3	2	3	2	0	1	5	0	7	3	3	5
Orius insidiosus, A	14	5	91	14	0	202	24	1	202	28	3	179	18	3	213
O. insidiosus, N	61	14	33	46	4	2	66	4	4	53	7	5	58	4	1
Geocoris sp., A	1	1	9	1	0	1	2	0	2	0	0	2	1	0	5
Geocoris sp., N	0	0	20	0	0	0	0	0	2	1	0	3	0	0	1
Macrosiphum pisi	29	10	0	19	3	1	27	1	0	62	3	0	52	2	0
Therioaphis maculata	866	628	2,162	1,079	394	1,198	888	46	566	868	45	306	764	76	661
Aceratagallia uhleri, A	15	35	87	29	47	46	17	1	22	24	5	15	23	18	42
A. uhleri, N	7	9	51	7	16	21	5	0	0	5	1	1	10	7	6
Empoasca fabae, A	39	16	49	39	12	42	51	1	28	70	2	28	29	1	28
E. fabae, N	98	15	31	110	23	9	75	25	15	130	44	19	115	7	7
Chrysopa plorabunda, A	14	9	1	12	2	3	13	1	0	9	0	0	6	1	0
C. plorabunda, L	0	4	14	1	1	15	3	0	6	2	0	5	0	2	11
Frankliniella occidentalis	19	6	78	35	5	72	45	7	235	39	5	178	33	6	92
Araneida	44	46	221	—	14	123	—	19	185	—	22	176	—	10	112
Other species	225	84	399	8	80	808	58	51	463	13	69	465	17	47	404
Totals	1,501	947	3,436	1,482	625	2,442	1,332	164	1,829	1,425	209	1,442	1,208	197	1,629

[a] The temperature was 87, 88, and 92° F., respectively, at the time the collections were made. Three was no wind.

taken. Toxaphene and endrin were every effective and residual. Other materials failed to reduce populations because of continued hatching of the eggs in the various plots.

Lygus lineolaris (P. deB.): Malathion was effective against nymphs and adults in the large scale test. No significant changes were noted in the small plots.

Nabis alternatus Parshley: Parathion and malathion were the only toxic materials against this species.

Orius insidiosus (Say): Endrin, toxaphene, parathion and demeton were very toxic.

Therioaphis maculatus: Parathion, demeton and endrin caused marked reductions; toxaphene was less effective in one test. There is evidence that this species increased in the large scale experiment because malathion killed great numbers of the convergent lady beetle.

Macrosiphum pisi: Biological control masked the direct effect of the insecticides on this species, but population increases were recorded in plots sprayed with parathion, toxaphene and demeton. Populations remained lower in the plots sprayed with endrin than in the checks.

Aceratagallia uhleri: Parathion, demeton and endrin were very effective; toxaphene less so.

Empoasca fabae (Harris): Parathion, demeton, and endrin were quite effective.

Chrysopa sp.: Population differences between treated plots and checks were not statistically significant.

Effect on the Diptera, Hymenoptera, and Araneida.—No evidence was found that any of the materials reduced fly populations. None of the insecticides had any measurable effect upon the populations of entomophagous Hymenoptera. There was also no relation between the numbers of spiders collected and spray treatments.

Parasite-Predator-Aphid Ratios in Sprayed and Check Plots.—Since the population of aphids was greater in the plots sprayed with certain of the insecticides, notably parathion and malathion, than in the checks, there was the possibility that these materials had made conditions more favorable for the aphids by killing their natural enemies. Comparable parasite-predator-host ratios were studied for all of the plots sprayed with parathion or malathion in 1954 and 1955 to determine this point. The data are shown in table 5. The natural enemy complex consisted of the convergent lady beetle, the *Aphidius* parasite (a Braconid that did not parasitize *Therioaphis maculata*) and *Chrysopa* species. In 1954 the aphid was *M. pisi* and in 1955 *M. pisi* and *T. maculatus*. It is seen that for 1954 (table 5) and for the large scale test in 1955 (table 5) following spraying there were more natural enemies per aphid in the checks whereas the reverse was true in the sprayed plots. June 4, 1954, these differences had disappeared possibly due to the greater attraction of the natural enemies to the heavier aphid populations in the sprayed plots. In the small plot tests in 1955, (table 5) the ratio was also more favorable in the check plots than in the parathion plots and increased slightly July 15 in the check plots. On the other hand, it

Table 5.—Parasite-predator-aphid population[a] ratios in alfalfa sprayed with malathion and parathion. 1954–1955.

Date	Numbers of Aphids per 125 Sweeps		Number of Enemies to Aphid	
	Untreated	Treated	Untreated	Treated
		Parathion, 1954		
Apr. 28	50	91	4.5– 1	1 – 1.2
May 5	5	32	12.4– 1	1.5– 1
May 22	13	38	1 – 1	1 –12.7
May 28	46	148	1 – 4	1 –29.6
June 4	413	940	1 –23	1 –16
June 9	290	553	1 – 9	1 –12.6
		Parathion, 1955		
July 6	895	915	1 –28	1 –34
July 8	639	47	1 –20	1 – 7.8
July 15	2162	566	1 –26	1 –70
		Malathion, 1955		
May 10	138	428	2.4– 1	1 – 3.6
May 17	56	197	1.1– 1	1 – 5.2
May 24	22	73	1.7– 1	1 – 2.4
May 31	38	145	1 – 2	1 – 6.3

[a] Aphids were primarily the pea aphid in 1954 and in 1955 the pea aphid and the spotted alfalfa aphid were involved.

continued to remain low in the parathion plots. The increase of the aphid population July 15 over that recorded July 8 was due to migration into the plots.

THE INFLUENCE OF POPULATION CHANGES CAUSED BY MIGRATIONS.—There was a continuous change in the quantitative species components in the unsprayed alfalfa between dates of sampling. Sometimes this was due to a combination of the attraction of large numbers of predators which was followed by a decline in their principal prey. The early heavy pea aphid population was practically wiped out in 1954, by a combination of lady beetles, lacewings, and a braconid parasite. The same was true for the spotted alfalfa aphid and the pea aphid in the large scale test in 1955. Just as soon as collections showed large numbers of thrips this was followed by large numbers of adult *Orius*, later by their nymphs and then both the thrips and *Orius* populations decreased.

Migrations into both sprayed and unsprayed plots tended to mask the effects of the insecticides. If this happened at or just before a spray treatment then it was possible to evaluate the effectiveness of the insecticides. This was the case with the alfalfa leafhopper in 1955. When migration came later as was the case often with the potato leafhopper or the six-spotted leafhopper, then no data were obtained.

The spotted alfalfa aphid has strong migratory tendencies. Therefore, records were taken in the small plot tests in 1955 of the percentage of winged aphids. At the time the plots were sprayed July 6, an average of 19.3% were winged, July 8, 23.1% and July 15, 40.4%. When comparisons were made of the effects of the insecticides by counts of wingless aphids it was found that there were 1706 in the check plots per 125 sweeps, compared with 829 for toxaphene-treated plots, 224 for endrin plots, 127 for parathion and only 32 for demeton plots. Thus an influx of winged aphids into all plots masked the real residual effect of these insecticides.

REFERENCES CITED

Ahmen, M. K., L. D. Newsom, R. B. Emerson, and J. S. Roussel. 1954. The effect of systox on some common predators of the cotton aphid. Jour. Econ. Ent. **47**(3): 445–9.

Fenton, F. A., and D. E. Howell. 1957. A comparison of five methods of sampling alfalfa fields for arthropod populations. Ann. Ent. Soc. America **50**(6): 606–11.

Gaines, R. C. 1954. Effect on beneficial insects of several insecticides applied for cotton insect control. Jour. Econ. Ent. **47**(3): 543–4.

van den Bosch, R., H. T. Reynolds, and E. J. Dietrick. 1956. Toxicity of widely used insecticides to beneficial insects in California cotton and alfalfa fields. Jour. Econ. Ent. **49**(3): 359–63.

Wene, G. P. 1953. Control of serpentine leaf miners on peppers. Jour. Econ. Ent. **46**(5): 789–93.

Wene, G. P. 1954. Effect of some organic insecticides on the population levels of the serpentine leaf miner and its parasites. Jour. Econ. Ent. **47**(5): 596–7.

Rotational Use of Spray Chemicals in Insect and Mite Control[1]

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ABSTRACT

Data secured from apple growers' spray schedules and from orchards sprayed with various experimental spray chemicals show that the development of resistance by orchard mites can be greatly retarded and possibly prevented entirely by the rotational use of spray chemicals with different killing actions. This is accomplished by killing any members of a population that are potentially resistant before actual resistance appears. In practice this is secured by frequently changing the type of spray chemical in use. The principle of successful rotational use applies to both insects and mites and should become increasingly useful as time passes and more organisms tend to develop the trait of resistance.

The word rotation means a series of events or positions that occur in order, always returning to the initial event or point, following which they repeat themselves in the same general pattern. In agriculture the word rotation is widely and favorably known. Here we have the rotation of crops, of pastures, of forest cutting or harvesting, and many others. These rotations are usually planned and under the control of man.

Agricultural rotations are used to gain increased production or other benefits and similar advantages apply to the rotational use of spray chemicals. Specifically, over a period of time, it is expected that better pest control will be gained with planned spray programs, which will tend to eliminate the disturbing feature of resistance on the part of different pests to spray chemicals.

HISTORICAL.—The development of resistance to certain spray materials on the part of certain pests has been known to entomologists for at least four decades. The most serious aspects and problems of resistance, however, have developed only within the last 15 years. Resistance has been found among all the important orders of insects and mites, and new cases are developing annually. Practically all of our better known and more efficient insecticides and acaricides have been rendered less effective by the appearance of this factor among insects and mites. Resistance is now one of the most serious of all insect control problems and as such demands the most serious consideration of possible plans for its abatement. All programs looking forward to this end must be given full consideration. It is believed that the idea of rotational use of spray chemicals is worthy of serious study.

There are, of course, changes in insecticide usage that are not rotational in character. The most common of these is the changing of spray chemicals that occurs when a new, more effective insecticide or acaricide is developed and takes the place of the older, less effective material.

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This is a well known phenomenon. For example, the codling moth (*Carpocapsa pomonella* (L.)) was first controlled by Paris green, then in order by calcium arsenate, lead arsenate, and finally by DDT. In the case of the plum curculio (*Conotrachelus nenuphar* (Hbst.)), Paris green was first used, then lead arsenate, BHC, certain phosphorus-based materials, and most recently dieldrin. For aphid control we first used tobacco infusions, then nicotine sulphate, and finally the phosphorus-based compounds. Numerous other examples could be cited illustrating this type of use. Though materials are changed, these changes are in no sense rotational since there is no cycle of use or return to the original spray material.

ROTATIONAL PATTERNS.—The first type of rotational use that has been employed has been essentially forced upon growers in their attempts to combat insect and mite resistance. A spray chemical that was highly effective when first used became of little value, and the grower was forced to use another material to obtain control. After a period of use, the new material also lost its effectiveness, and the grower was again forced to change. Finally it may have been found that the original spray chemical had regained its effectiveness and it again could be employed in control practices. Examples of this forced rotation are well illustrated by the case of the common house fly (*Musca domestica* L.), the two-spotted spider mite (*Tetranychus telarius* (L.)), and the European red mite (*Panonychus ulmi* (Koch)). Fortunately our chemists and entomologists have developed new spray chemicals so that we have had new materials at hand that could take the place of the old. However, with new cases of resistance developing on every hand, we do not have the assurance that new and effective spray chemicals will always be available when needed.

A second type of rotational use is now suggested. It may be called a voluntary or planned rotation having as its purpose the elimination or significant reduction of the incidence of resistance to spray chemicals by insects and mites. This method of procedure is possible because there are at present numerous insecticides and acaricides with different killing actions. For example, the many acaricides may be divided into groups according to their chemical compositions inasmuch as they cause death by different physiological reactions following their use. These materials and their grouping are as follows:

Acaricide Groups[2]

1. Phosphorus-based materials:
   TEPP, parathion, malathion, EPN, Diazinon, demeton (Systox), Trithion, Thimet, Hercules AC-528 (Delnav), ethion, Guthion, Phosdrin, phosphamidon, etc.
2. Dinitros:
   DN-289-Elgetol 318 (for dormant use), DN-111, Dry Mix No. 1, Elgetol
3. The petroleum oils (With varying specifications)
4. Glyodin (Crag Fungicide)
5. Kelthane Chlorobenzilate
6. Dimite
7. Sulfur-based compounds:
   Aramite, Genite EM-923, Chlorbenside, ovex, Tedion, Sulphenone, etc.

In rotational use, when a grower wishes to change from one acaricide to another, he should always select a material from a different group rather than one from the same group as the material that he has been using. Thus, he would subject the insect or mite population to a material with a different killing action, eliminating, perhaps, many individuals which were resistant or potentially resistant to the original spray chemical. This pattern, if followed in turn with other spray chemicals of different types, should definitely retard the development of resistance.

Table 1.—Rotational schedule of spray chemicals for the control of *Panonychus ulmi* (Koch).

YEAR	EARLY SEASON	LATE SEASON
1959	DN-289	Ovex (2 applications)
1960	Oil	Demeton (2 applications)
1961	Genite 923 in pink	Kelthane (2 applications)
1962	Repeat 1959	Repeat 1959

An example of a spray schedule using the chemicals in rotation is presented in table 1. It should be borne in mind that this is only an example showing one possible arrangement of chemicals of different groups that can be used in rotation.

SUPPORTING DATA.—Numerous other instances in which pests may be controlled in this manner may be cited. For example, four different chemical groups, namely, (1) arsenicals, (2) chlorinated hydrocarbons, (3) phosphorus-based chemicals, and (4) certain carbamates, can be used against the codling moth. It is believed that a rotational program with these chemicals would be of definite and long-lasting value.

The data supporting the theory of planned rotational use have been secured by working with numerous Ohio growers for the last 15 years and by a special study of three experimental orchards at Wooster, Ohio.

The work with growers involved a review of each annual spray schedule as correlated with control results for the various pests. During the past several years, it has been noted that growers who made frequent changes in the spray chemicals that were being used obtained better control, especially where mites were concerned. For example, one grower who always used dormant oil or dormant dinitro and alternated between phosphorus-based and sulphur-based acaricides for summer use has not had a serious mite problem for over 10 years.

On the other hand, numerous growers who have restricted themselves to the use of one acaricide for several seasons have always developed resistant mite populations which, before resistance was suspected, did a great deal of damage. In the hands of growers, the rotational use of acaricides, frequently by chance, has produced good results, whereas generally poor results have occurred when one spray chemical has been used continuously.

The experimental orchards at Wooster, Ohio are owned

[2] Chemical names of these compounds are given in the Jour. Econ. Ent. **50**: 226–228. April, 1957, except as listed below.

1. Phosphorus-based materials:
   Ethion (*O,O,O',O'*-tetraethyl *S,S'*-methylene bisphosphorodithioate)
   Phosphamidon (dimethyl-diethylamido-1-chloro-crotonyl (2)-phosphate)
2. Dinitros:
   Elgetol (4,6-dinitro-o-sec-butylphenol, sodium salt)
   DN-289 or Elgetol 318 (4,6-dinitro-o-sec-butylphenol, triethanolamine salt)
   DN-111 (4,6-dinitro-o-cyclohexylphenol N,N-dicyclohexylamine salt)

Table 2.—Results of tests with acaricides against mites in 1950 and 1958.

Year	Material per 100 Gallons	Mites per Leaf and Counting Interval		
		Pre-Spray	4 Days	15 Days
1950	Aramite, 1.5 lb.	3.4	1.9	3.0
1958	Aramite, 1.5 lb.	5.1	0.6	2.0
1950	EPN 27.5%, 4 oz.	0.7	0.0	1.1
1958	EPN 25%, 4 oz.	6.9	0.9	5.0
1950	Parathion 15%, 8 oz.	2.2	1.2	6.6
1958	Parathion 15%, 8 oz.	6.1	2.1	16.7

and operated by the Ohio Agricultural Experiment Station. The first orchard group has been sprayed with the best commercial schedules that are available and designed for the production of high quality fruit. This has involved rather frequent changes in spray chemicals as new, safe, and effective materials have been developed. These changes have not been as frequent as would occur in a planned rotational schedule, but the results have been generally good. In only a few seasons in the last 15 years have difficulties with mites or insects occurred in these orchards. The different orchards in this group vary in age and size so that the problem of spray application is considered as average.

The second orchard is now 35 years of age and contains eight commercial varieties of apples. Since 1935 or for a period of 23 years, this orchard has been used almost exclusively for the testing of different acaricides. Thus, over this period of time no spray chemical has been used continuously on any particular group of trees. This means that a type of rotational use of spray materials has now been employed for 23 years. It is admitted that the changes have been more frequent than would occur in any planned rotation program, but the results to date have been outstanding. No resistance to any acaricide has appeared. Spray chemicals that were used 10 or 15 years ago, whether effective or not, can be reintroduced in the orchard and control results will be practically the same as when first used. Any reasonably effective acaricide, if properly applied, will still give good mite control. All the evidence and data from this orchard support the theory of rotational use.

For example, in 1950 tests were conducted with Aramite, EPN, and parathion against the European red mite in this orchard. In 1958 an identical series of tests was made on the same trees using the same materials at the same dosage and at approximately the same time. The only significant difference was that in 1958 a higher mite population was present at the time of the spray application. This accounts for somewhat higher populations following spraying in 1958. The results are shown in table 2. Considering all factors, there was no significant difference in control in 1950 and 1958.

Table 3.—Results of tests with EPN and parathion against mites in 1949 and 1958.

Year	Material and Ounces per 100 Gallons	No. of Applications	Mites per Leaf[a]			
			Pre-Spray	1	2	3
1949	EPN 35%, 4	3	7.2	1.3	1.3	0.4
1958	EPN 25%, 4	2	6.5	2.3	1.7	1.
1949	Parathion 25%, 5	3	9.4	19.3	16.5	19.4
1958	Parathion 15%, 12	2	6.9	6.8	5.0	6.3

[a] Dates of counts: 1949 Pre-spray, June 14; 1, June 29; 2, July 12; 3, July 26. 1958 Pre-sprav, July 3; 1, July 11; 2, July 18; 3, July 25.

Other comparisons of data lead to the same conclusion as shown by the following examples. In 1949, a test schedule of three applications of EPN and parathion was applied. The results when compared with those of a schedule of two sprays of the same materials used in 1958 are shown in table 3.

In the case of the 1949 EPN schedule, the three applications containing approximately 100% more toxicant might be expected to give better control. The data show a trend in this direction, but the differences are not significant. On the other hand, the parathion schedule of 1949 had slightly less toxicant than that of 1958, and it is largely due to this factor that the 1958 results with parathion were better than those in 1949.

Other examples and comparisons of data could be made, all showing that no resistance on the part of the European red mite to acaricides has developed in this orchard.

The third orchard is young, being only 9 years of age. Five years ago it was divided into plots and these have been sprayed on a rotational schedule. So far no resistance on the part of mites has been noted, although the period of time is admittedly too short to produce definite results.

Another factor that supports the idea of rotational use of spray chemicals is the fact that mites gradually lose their resistance to a specific chemical when other chemicals with different killing actions are used against them. This has been demonstrated for orchard mites by Cutright (1956). In the control of mites in greenhouses, it has been noted by numerous research workers (Neiswander *et al.* 1950).

References Cited

Cutright, C. R. 1956. A three year field study of a mite population resistant to parathion. Ohio Agric. Expt. Sta. Res. Circ. **37.**

Neiswander, C. R., J. G. Rodriguez, and R. B. Neiswander. 1950. Natural and induced variations in two-spotted spider mite populations. Jour. Econ. Ent. **43**(5): 633–6.

Effects of Temperature and Plant Species upon the Rates of Metabolism of Systemically Applied Di-Syston[1,2]

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Abstract

The rates of oxidative metabolism and of hydrolytic decomposition of Di-Syston®, or *O,O*-diethyl *S*-ethyl-2-thioethyl phosphorodithioate (formerly called Bayer 19639) were measured at various temperatures and in several plant species using a P^{32}-radiotracer. The rates of oxidation of the Di-Syston metabolites in isolated cotton leaves were accelerated by increased temperatures between 37° and 100° F., and from the Arrhenius energy of activation 10,200 cal. per mole it was determined that the rate of oxidation of Di-Syston sulfoxide increased about 1.9 times for each 10° C. rise in temperature. Metabolism of Di-Syston sulfoxide and hydrolytic decomposition of the toxic products occurred from 2 to 3 times as fast in tomato leaves at 70° F. as in cotton leaves. The rates in a number of other plants studied appeared to be intermediate between those in tomato and cotton.

Di-Syston has proved to be an effective systemic insecticide and is especially promising for use as a seed treatment or as a granulated formulation for soil applications (Reynolds *et al.* 1957). It has been shown to undergo oxidative metabolism in cotton and alfalfa plants and is rapidly converted to its sulfoxide derivative and more slowly to the sulfone, and also to the sulfoxide and sulfone of the corresponding phosphorothiolate (Metcalf *et al.* 1957). The rate at which these toxic oxidative derivatives are formed has a decided bearing upon the performance of the systemic treatment and upon the nature and magnitude of the toxic residues in plant tissues. The investigations reported here were undertaken to provide more definite information regarding the effects of environmental temperature and plant species upon the rates of metabolism.

Materials and Methods.—The basic tools for this investigation were the use of P^{32}-labeled Di-Syston, very kindly provided by Dr. Gerhard Schrader of Farbenfabriken Bayer, Leverkusen, Germany, and paper chromatography and quantitative serial Geiger counting and radioautography as described by Metcalf *et al.* (1957). The radioisotope was 99.9+% pure as evaluated by paper chromatography and had an initial activity of 14.2 c.p.s. per γ. The Di-Syston was mixed with 3 parts of polyglycol emulsifier (8139 Thiosolve), and a colloidal suspension formed in distilled water at a concentration of approximately 0.1%. Fresh leaves of various plants were trimmed at the bottom of the petiole and quickly immersed in this solution and then placed in the sunlight for 30 minutes to 1 hour until the uptake of radioactive tracer (0.5 to 1 ml.) was sufficient to enable accurate measurement of the metabolic products. The leaves with petioles in distilled water were then transferred in groups of five to constant temperature rooms at 37°, 50°, 70° and 100° F. under a battery of six 40-watt fluorescent lights at a height of about 2 feet above the leaves. Assay was carried out by pooling 0.1-gm. portions collected from each of the five leaves, homogenizing in 10 times the weight of water, centrifuging, and partitioning the radioactivity between chloroform and water. After determining the partition coefficient, the remainder of the chloroform layer was evaporated under an air jet and the organophosphorus esters taken up in a minute drop of acetone for application of paper chromatography. The isolated leaves were used rather than intact plants to permit the very rapid uptake of the radiotracer and thus to permit the study of the rates of metabolism uncomplicated by the continual accumulation of translocated material.

Results.—*Effects of environmental temperature.*—Investigations of the rate of metabolism of Di-Syston in cotton leaves were carried out under constant temperature conditions of 37°, 50°, 70°, and 100° F. with constant artificial light. The results at 70° were in complete agreement with those previously obtained under normal greenhouse conditions at approximately 80 to 85° F. (Metcalf *et al.* 1957). Paper chromatograms of the chloroform soluble radioactivity from the treated leaves, as shown in figure 1, clearly indicated the presence of four radioactive components other than Di-Syston (R_f 0.99). These had previously been shown to be *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorothiolate (IV) (R_f 0.00–0.04); *O,O*,-diethyl *S*-ethyl-2-sulfonylethyl phosphorothiolate (V) (R_f 0.03–0.08); *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorodithioate (II) (R_f 0.18); and *O,O*-diethyl *S*-ethyl 2-sulfonylethyl phosphorodithioate (III) (R_f 0.64). It is clear from figure 1 that increased temperatures accelerate the formation of the highest oxidation products, the sulfones, as would be predicted from chemical kinetics. Quantitative evaluation of the amounts of each compound present in the chromatograms after 1, 2, 4, and 7 days gave the information presented in table 1. From this, the curves for the consecutive reactions taking place at the various temperatures were prepared (fig. 2) and found to be very similar to those previously determined (Metcalf *et al.* 1957).

In order to give an overall impression of the data in table 1, the three dimensional surfaces of figure 3 were constructed. These show the relationships between temperature-time-rate of disappearance of compound II, *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorodithioate; and between temperature-time-rate of formation of compound IV, *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorothiolate. These models graphically demonstrate the influence of temperature from 0 to 100° F. on the oxidative processes. The trough in the lower portion of the figure is apparently a result of differential rates in the formation of the metabolite and its removal by further oxidation of the sulfone.

The rate of change of the partition coefficient for $CHCl_3/H_2O$ can be interpreted in terms of loss or destruction of the intact esters II, III, IV, and V which partition about 99:1 in the chloroform phase, and the formation of hydrolytic products which are relatively non-toxic

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Table 1.—Relative amounts of P^{32} Di-Syston and oxidative metabolites in chloroform extract of cotton leaves held at constant temperatures (° F.).

		Per Cent of Total P^{32} at Indicated Days After Treatment															
		1				2				4				7			
		37°	50°	70°	100°	37°	50°	70°	100°	37°	50°	70°	100°	37°	50°	70°	100°
$(EtO)_2P(S)SC_2H_4SEt$	I	2.3	5.1	1.0	0.8	4.6	0.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
$(EtO)_2P(S)SC_2H_4SOEt$	II	90.0	83.5	72.8	66.4	79.5	78.8	60.6	49.4	75.5	72.1	45.2	33.2	78.0	71.6	39.1	26.8
$(EtO)_2P(S)SC_2H_4SO_2Et$	III	2.9	5.5	8.3	16.3	10.2	11.0	15.3	22.3	5.14	13.0	25.1	27.0	8.3	15.4	27.7	26.5
$(EtO)_2P(O)SC_2H_4SOEt$	IV	5.0	5.9	17.8	14.0	14.0	12.2	18.3	17.4	17.6	10.0	20.3	28.3	17.4	9.8	21.6	22.4
$(EtO)P(O)SC_2H_4SO_2Et$	V	0.0	0.0	0.0	3.0	0.0	0.0	5.9	10.9	0.0	4.9	8.9	11.5	0.0	3.2	11.5	24.2
Partition $CHCl_3/H_2O$		10.0	6.4	6.6	5.3	5.0	5.6	4.3	3.8	3.9	5.8	2.9	2.0	2.8	7.0	2.3	2.1

and partition 99:1 in the aqueous phase. It will be seen from the data in table 1 that this process occcurs quite rapidly with time and is also accelerated with increased temperatures.

As previously reported (Metcalf *et al.* 1957), the oxidation of the sulfide, Di-Syston, to the sulfoxide (II) occurred so rapidly at temperatures above 70° F. that only traces of the sulfide could be detected, even at intervals as short as 1 hour after treatment. The rate of oxidation was enough slower at 37° and 50°, so that small amounts of the sulfide were found during the initial stages of the experiment.

The major component in the leaves during the entire experiment was the Di-Syston sulfoxide (II). From the consecutive reaction curves plotted from the figures in table 1, it was possible by plotting log. conc. vs. time to calculate the rate constants for the disappearance of II at various temperatures, according to the equation:

$$-\frac{d\,[\mathrm{II}]}{dt}=[\mathrm{II}]\,k$$

where $k=k_1+k_2$, the rate constants for the oxidation of the sulfoxide to the sulfone (III) and thiol analogue sulfoxide (IV), respectively. From these calculations the following values of k were obtained graphically: 37° F. (2.8° C.), $k=0.0011$ hr.$^{-1}$; 50° F. (10.0° C.), $k=0.0016$; 70° F. (21.1° C.), $k=0.0037$; 100° F. (37.8° C.), $k=0.0096$.

When these k values were plotted as $-\log. k$ vs. $1/T$ as in the standard Arrhenius plot for energy of activation (Glasstone 1940), a straight line relationship was evident as shown in figure 4, with a slope of 2000×10^3 for A/R. Thus, A (the energy of activation) was determined to be 10,200 calories per mole for the oxidation of compound II. From this information it was shown that the rate of disappearance of the compound II was increased, approximately 1.86 times for each 10° C. rise in temperature. Similar effects of temperature must be presumed for the other oxidative reactions since the equations for their reaction rates are not amenable to simple mathematical solution.

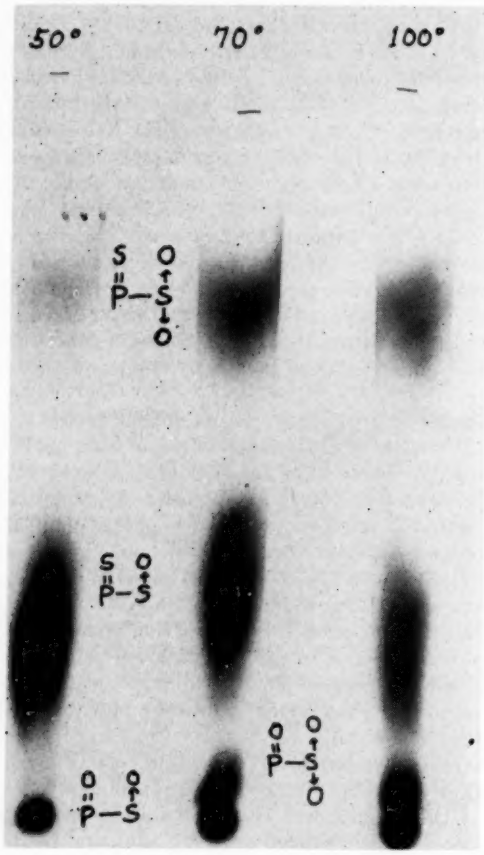

FIG. 1.—Radioautographs of paper chromatograms showing chloroform-soluble metabolites of P^{32} Di-Syston formed after 3 days in cotton plants at the indicated temperatures. From bottom to top, the spots represent metabolites IV, V, II, and III (see text).

Metabolism in Other Plant Species.—The rates of metabolism of Di-Syston taken up by isolated leaves were studied under conditions of constant light and at a constant temperature of 70° F. The species investigated were alfalfa, avocado, bean, brussel sprouts, cabbage, corn, cotton, lemon, tomato and zinnia.

In all of these plants, the metabolism of Di-Syston took place qualitatively as observed in cotton (Metcalf *et al.* 1957). No trace of the parent material, *O,O*-diethyl *S*-ethyl-2-thioethyl phosphorodithioate, could be detected in any species at the 1-day interval after application. However, each of the four oxidative metabolites II, III, IV, and V was found by paper chromatography and these appeared at intervals and in such quantities as to demonstrate that the metabolism was proceeding qualitatively as depicted in figure 2. As might be expected, there were significant differences in the rates of metabolism. Some difficulty was experienced in obtaining complete pictures with certain plant species because of difficulties in promoting the uptake of the P^{32} Di-Syston, in extracting the metabolites and freeing them from fatty substances which interfered with paper chromatography, and in preventing the leaves from wilting during the course of the experi-

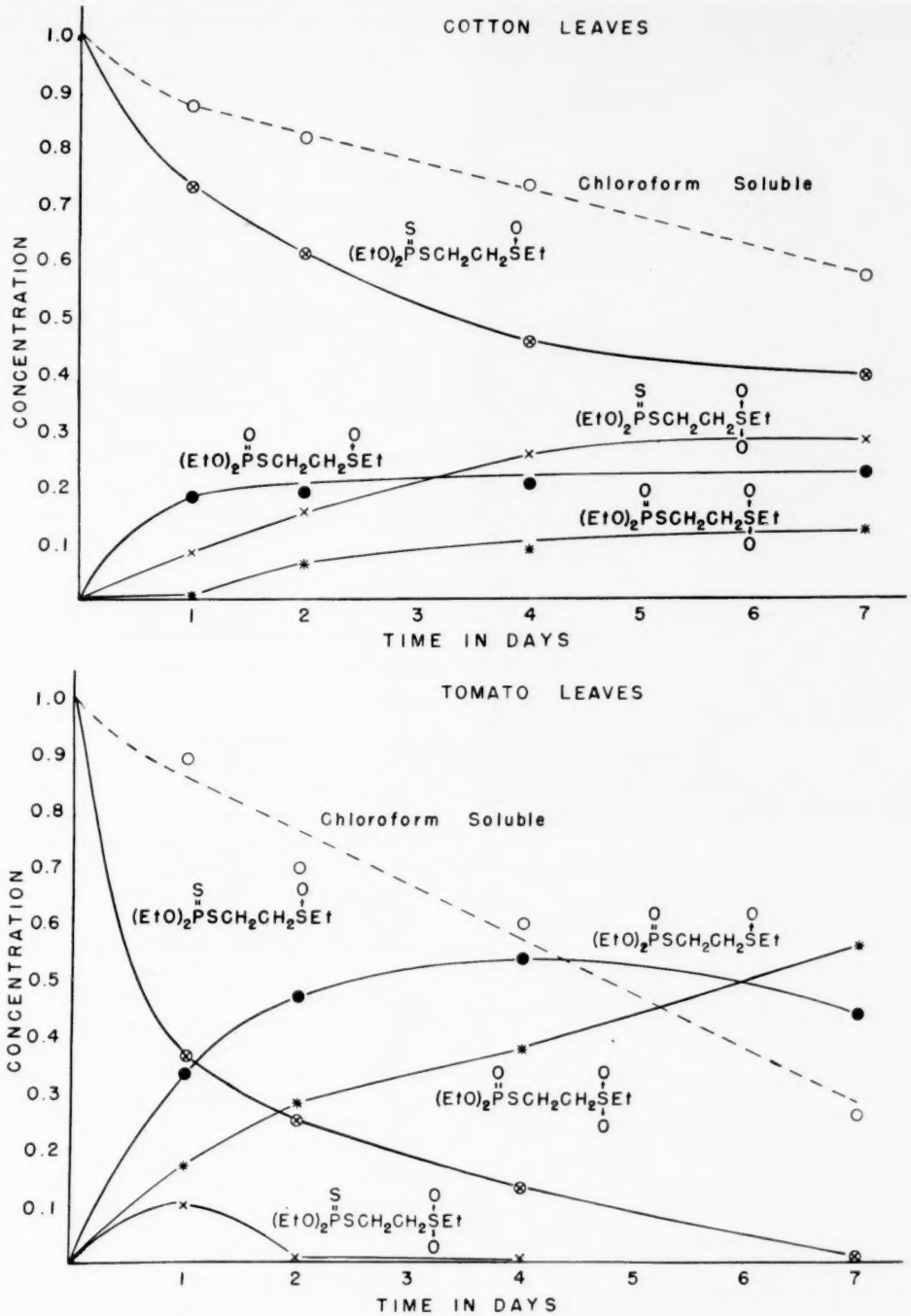

FIG. 2.—Graphs comparing relative amounts of Di-Syston metabolites as fractions of total chloroform-partitioning P^{32} in extracts of isolated cotton (top) and tomato (bottom) leaves at various intervals after treatment. The values for the chloroform-soluble material (dotted lines) represent the fractions of total P^{32} which partitioned into chloroform.

ment. Relatively complete data were obtained for both cotton and tomato, and as these two plants appear to represent the extremes in the rates found, the complete diagrams for the rates of consecutive reactions occurring in these are plotted in figure 2. These reaction rates have been found to be relatively consistent upon several redeterminations with each species. It will be noted that the rate of oxidation of Di-Syston sulfoxide, compound II, was approximately three times as great in the tomato leaves as in cotton, the rate constants at 70° F. being $k=0.014$ hr.$^{-1}$ and $k=0.0037$ hr.$^{-1}$, respectively. Thus, over the 7-day period of the experiment, a far greater proportion of metabolites *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorothiolate (IV), and *O,O*-diethyl *S*-ethyl-

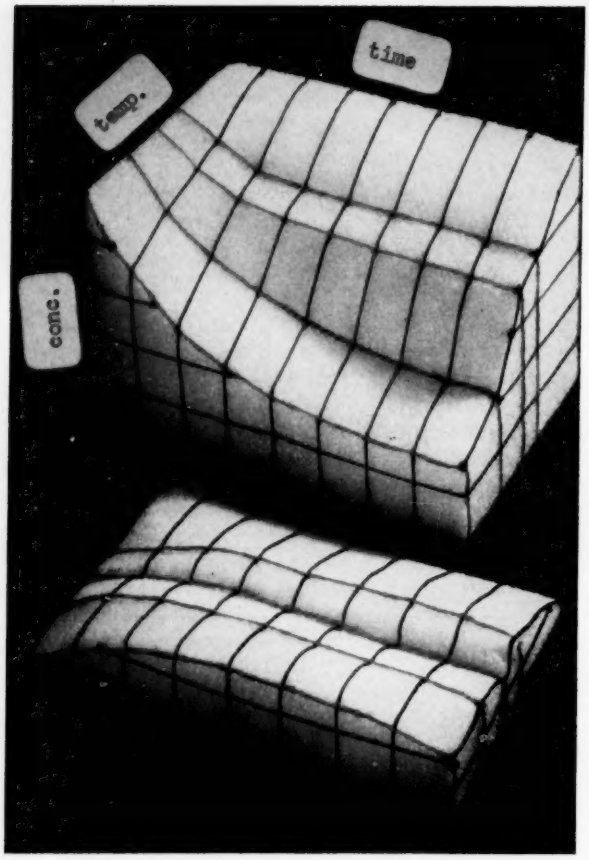

FIG. 3.—Photographs of three-dimensional surfaces showing the relationship of time and temperature to loss of *O,O*-diethyl *S*-ethyl 2-sulfinylethyl phosphorothionate (above) and formation of *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorothiolate (bottom) in cotton leaves:

Y-axis represents fraction of total chloroform-soluble radioactivity, X-axis time in days, and Z-axis temperature from 100° F. (front) through lines at 70° F., 50° F., 37° F. to 0° F. at rear.

2-sulfonylethyl phosphorothiolate (V) were formed in the tomato leaves, and these constituted the only toxic metabolites present at the end of the 7-day period. Of the other species studied, the rates of oxidation in alfalfa, bean, cabbage, brussel sprouts, and zinnia were approximately the same as those determined for cotton, while those in corn were appreciably faster but not quite as rapid as in the tomato.

Detoxication in Plants.—As mentioned above, the chloroform/water partition coefficient of the P^{32} radioactivity conveniently serves as a measure of the rate of conversion of the toxic Di-Syston metabolic products by hydrolysis to nontoxic water-soluble products. This technique has been applied to the study of Di-Syston metabolism in the leaves of a number of plant species as shown in table 2 (see also fig. 2). The partition coefficients decrease quite rapidly for most of the plants studied and at fairly comparable rates. The rates of decomposition are in good agreement with the rates of oxidative metabolism. For cotton and tomato, the rate of decrease of the chloroform-soluble fraction of the total P^{32} in the leaves gave a

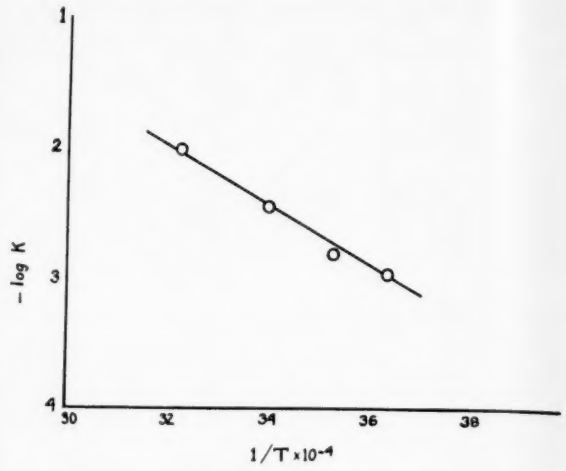

FIG. 4.—Arrhenius plot of $\log_k$-values for oxidation of *O,O*-diethyl *S*-ethyl-2-sulfinylethyl phosphorodithioate in cotton leaves at various temperatures.

straight line relationship (fig. 2). The relative slopes of these lines, 0.34 for cotton leaves and 0.68 for tomato leaves, indicate that the rate of metabolic detoxication is twice as fast in tomato as in cotton. The most notable exception was the lemon in which the P^{32} activity remained relatively constant in the chloroform phase for at least 2 weeks. Paper chromatography showed the presence of large amounts of intact Di-Syston and very slow conversion to the other oxidative products.[3]

This suggests that the oil-soluble esters are being protected from aqueous hydrolysis by the oil content of the leaves and this is confirmed by the radioautograph of figure 5 which shows that nearly all of the radioactivity from P^{32} Di-Syston translocated into a lemon leaf is confined to the oil glands. For comparison, a similar radioautograph of Systox-thiol-isomer translocated into lemon leaves showed (Metcalf *et al.* 1954) that most of the radioactivity was located in the aqueous tissues of the plant. These differences are correlated with the relative water solubilities of the compounds, *i.e.*, Di-Syston 66 p.p.m., Systox thiol-isomer 3900 p.p.m. (Metcalf *et al.* 1957).

DISCUSSION.—The rate at which toxic oxidative metabolites are formed and the eventual degradation to nontoxic derivatives has a decided bearing upon the nature

[3] We wish to acknowledge the assistance of Dr. Richard Leski in this experiment.

Table 2.—Change in chloroform/water partition coefficient of P^{32}-Di-Syston metabolites in various plant species at 70° F.

PLANT	DAYS AFTER APPLICATION							
	1	2	3	4	5	7	12	14
Alfalfa	10.1	7.6	6.7	6.4	5.2	4.1		
Avocado	9.6	10.9	5.3	0.9		2.9		
Bean	6.4		2.9		2.2			
Brussel sprouts	10.4	8.5	5.8					
Cabbage	10.0	8.3		4.9		1.4		
Corn	9.8		5.5		1.7			
Cotton	6.6	4.3		2.9		2.3		
Eggplant	15.0	5.9		2.9				
Lemon	11.4				9.1			15.2
Squash	6.3		3.9		0.9			
Tomato	8.2	2.3		1.2		0.35		
Zinnia	8.5	13.5		3.8		3.8		

and magnitude of toxic residues in plant tissues. A number of previous authors in speculating upon potential residue problems following various methods of treatment with systemic insecticides concluded that persistence curves should be established on different crops grown under different environmental conditions. It was demonstrated, for example, that when alfalfa seed was treated with Thimet or Di-Syston the effectiveness for aphid control and consequently the toxic residues varied for as much as several weeks depending on rate of plant growth —the slower the plant growth (resulting from cool weather), the longer the persistence (Reynolds *et al.* 1957). In experiments with P^{32}-schradan, Heath *et al.* (1952) concluded that the rate of breakdown varied little with plant species among strawberries, sugar beets, hops and brussel sprouts, but decreased with the time of year from May to October. In contrast, however, Thomas & Bennett (1954) showed that the breakdown of schradan into nonchloroform extractables varied with species and was far greater in beans than in *Coleus*.

The results reported in this paper then have a distinct bearing on the problem of toxicity to pest species and residues resulting from treatment with systemic insecticides. As metabolism of Di-Syston proceeds very rapidly in tomato, one could expect no more than a short period of toxic activity to pest species unless the treatment is such as to provide a prolonged uptake of material; and, analogously, toxic residues should persist for only a relatively short time. On the other hand, in the case of cotton, metabolism proceeds much more slowly than in tomato, and it has been shown from results obtained in the field that toxicity persists for several weeks. Similar variations among different plant species occurred in these tests, and there is no reason to believe that variations equally as great would not occur among other as yet untested plant types.

It was demonstrated that temperature, by its general effect on chemical kinetics and by governing the rate of physiological activities of the plant, plays a large and fortunately somewhat predictable role in metabolism of systemic insecticides within a plant. The anticipated increased problem with toxic residues may not be as great as first thought in the case of systemic treatments applied at time of planting because when cool temperatures slow the rate of metabolism, and thus lengthen the period of toxic residues, the rate of plant growth also proceeds more slowly, prolonging the date of crop maturity. The opposite is true, of course, during periods of warm weather. Such a governing mechanism may be beneficial as the period of toxic activity is adjusted to some extent to the period of needed pest control. Applications made after the plants are established or when the crop is approaching harvest must be considered carefully as conceivably a drastic change in temperature could affect the rate of degradation of the toxic metabolites, and thus the magnitude of toxic residues in the plant. The rate of metabolism among different plant types or as affected by temperature, therefore, will have a profound effect upon field usage of systemic insecticides, particularly in regard to time of application prior to harvest of an edible crop and to the desired period of toxicity to pest species.

FIG. 5.—Radioautograph of lemon leaf 7 days after application of P^{32} Di-Syston to base of stem.

Finally, the information on the rate of formation of the toxic metabolites has a significant bearing on the determination of residues by the cholinesterase technique. The final oxidative metabolite V is from 5 to 10 times more active as a cholinesterase inhibitor than any of its precursors (Reynolds *et al.* 1957). Therefore, it is obvious that the presence of this compound in relatively large amounts, such as were found in tomato leaves after 7 days, would result in higher cholinesterase inhibition (and consequent higher apparent residue values) than those obtained from an equivalent amount of total Di-Syston metabolites after 7 days in cotton leaves (fig. 2).

REFERENCES CITED

Glasstone, S. 1940. Text-Book of Physical Chemistry, p. 1068. D. Van Nostrand Co., Inc., N. Y.

Heath, D. F., D. W. J. Lane, and Margaret Llewellyn. 1952. Octamethyl pyrophosphoramide in the living plant. Jour. Sci. Food and Agric. **1952,** pp. 60–73.

Metcalf, R. L., R. B. March, T. R. Fukuto, and M. Maxon. 1954. The behavior of Systox-isomers in bean and citrus plants. Jour. Econ. Ent. **47**(6): 1045–55.

Metcalf, R. L., T. R. Fukuto, and R. B. March. 1957. Plant metabolism of dithio-Systox and Thimet. Jour. Econ. Ent. **50**(3): 338–45.

Reynolds, H. T., T. R. Fukuto, R. L. Metcalf, and R. B. March. 1957. Seed treatment of field crops with systemic insecticides. Jour. Econ. Ent. **50**(5): 527–39.

Thomas, W. D. E., and S. H. Bennett. 1954. The absorption, translocation, and breakdown of schradan applied to leaves, using P^{32}-labeled material. Ann. Appl. Biol. **41:** 501–19.

California Desert and Coastal Populations of Flying Aphids and the Spread of Lettuce-Mosaic Virus[1]

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Abstract

The population of efficient vectors, mainly the green peach aphid, *Myzus persicae* (Sulz.), during the growing season determined the rate of spread of the lettuce-mosaic virus. A high population of the melon aphid, *Aphis gossypii* Glover, did not cause measurable spread, even though this insect was shown to be a fairly good vector of lettuce-mosaic virus in the laboratory. The lettuce seed-stem aphid, *Macrosiphum barri* Essig, was shown to be an efficient vector in the laboratory.

The lettuce-mosaic virus is both seed-borne and aphid-borne. Newhall (1923) first reported the transmission of this virus through the seed of diseased lettuce, *Lactuca sativa* L., plants, while Jagger (1921) first reported aphid transmission. Grogan *et al.* (1952) reported that seeds from infected plants of American commercial varieties produced 1 to 3% infected seedlings. They also showed a method of producing virus-free seed and presented data showing that except under certain unfavorable conditions the use of virus-free seed would reduce loss from lettuce mosaic. They also discussed the effect of aphid populations in desert and coastal areas on mosaic incidence. They believed that the failure of lettuce mosaic to cause damage in the Imperial Valley is explained by low aphid populations in the fall and winter during the period that lettuce is grown, while high coastal aphid populations during the growing season cause rapid spread of the virus. Casual observation by the authors indicated that the population of flying aphids in the desert was often quite high in the fall, apparently higher than in coastal areas where spread of lettuce mosaic was taking place. The study described in this paper was conducted to discover the size and composition of aphid populations during the lettuce-growing season in the two areas and their effects on the incidence of lettuce mosaic.

Materials and Methods.—Aphids were trapped on yellow-painted board traps, 5 by 10 inches, covered with sticky tree-banding material. These boards were hung between horizontal arms attached to posts located near the margins of lettuce fields. The tops of the traps were about 5 ft. above ground level. The exposed sticky boards were replaced at intervals of 1 to 2 weeks and taken to the laboratory where the aphid catch (or an aliquot) was removed, washed in chloroform, and heated in a mixture composed of lactic acid, acetic acid, phenol, ethyl alcohol, and water. This restored the aphids to a plump condition and partly cleared them. They were then identified to species and the number of each species recorded.

Certain aphid species which were found to be numerous in the flying populations were established in the greenhouse and tested for ability and efficiency in the transmission of the lettuce-mosaic virus. Test insects were starved 2 or more hours, fed on diseased lettuce for 2 to 5 minutes, and then transferred to healthy lettuce seedlings with two to four true leaves. About 20 aphids were transferred to each test plant, left there for 2 to 3 days, then killed by fumigation. When available, check plants were infested with noninfective aphids or left uninfested. None of the check plants developed symptoms of lettuce mosaic. Early test plants were grown from seed furnished by R. G. Grogan and later plants from seed from the Associated Seed Growers Co.

Vector Identity and Efficiency.—About 20 species of aphids have been recorded from *Lactuca sativa* L. and about 30 more from other species of *Lactuca*. These records may be found in Patch (1938), Börner (1952), and Palmer (1952). In southwestern United States and northwestern Mexico only five aphid species breed up large populations on lettuce. These, together with other generic or specific names used for them, are:

The green peach aphid, *Myzus persicae* (Sulz.) (*Myzodes, Nectarosiphon*).

The potato aphid, *Macrosiphum solanifolii* (Ashmead) (*Macrosiphon, Illinoia, Nectarophora, euphorbiae* Thomas, *gei* Koch, *lactucae* Schrank).

The lettuce seed-stem aphid, *Macrosiphum barri* Essig, (*Metopolophium, Aulacorthum*).

The lettuce root aphid, probably *Pemphigus bursarius* L., (*Prociphilus, betae* Doane). For details of life history see Lange *et al.* (1957).

The brown ambrosia aphid, *Macrosiphum ambrosiae* (Thomas), (*Paczoskia*). This may be a complex rather than a single species.

The 10 species of aphids tested as vectors of lettuce-mosaic virus were four of the above species and six others selected as most common in the area or as breeding on plants related to lettuce. The lettuce root aphid could not be tested since it does not occur where our experimental work was done.

Results (table 1) showed that of the 10 aphids tested three species commonly breeding on lettuce in this area are efficient vectors while two species not breeding on let-

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Table 1.—Results of tests of several aphid species as vectors of lettuce mosaic.[a]

Species	Aphids Used	Plants Used	Per Cent Plants Infected	Aphids per Infection
Amphorophora sonchi	628	30	6.7	314
Aphis gossypii	717	38	13.2	143
Aphis medicaginis	644	30	0	—
Hyalopterus pruni	618	31	0	—
Macrosiphum ambrosiae	600	30	0	—
Macrosiphum barri	722	33	48.5	45
Macrosiphum solanifolii	640	32	53.1	38
Myzus persicae	640	33	42.4	46
Rhopalosiphum maidis	515	30	0	—
Therioaphis maculata	671	33	0	—

[a] Diseased to healthy lettuce.

tuce are inefficient vectors. The other five species are nonvectors. The green peach aphid and the potato aphid are indicated as efficient vectors of the lettuce-mosaic virus. This generally agrees with previously published work although Ainsworth & Ogilvie (1939) found the potato aphid a less efficient vector than the green peach aphid. Both of these species commonly breed on lettuce in all southern California. The lettuce seed-stem aphid, *Macrosiphum barri* Essig, is here first reported to be a vector of the lettuce-mosaic virus. It appears to be as efficient a vector as the two species discussed above. The seed-stem aphid usually does not build up as high populations as the other two except on lettuce seed stems, where it surpasses them.

The melon or cotton aphid, *Aphis gossypii* Glover (*Cerosipha, Doralina, Doralis*) breeds on many plants, but apparently not on lettuce. These tests showed it to be a vector but to be significantly less efficient than the three species above. These results generally agree with those of Fry (1952), although all his vectors showed high efficiencies.

The sow-thistle aphid, *Amphorophora sonchi* (Oestl.) (*Nasonovia, Hyperomyzus lactucae* L.) breeds commonly on *Sonchus* spp. and on wild lettuce, *Lactuca* sp., but apparently not on cultivated lettuce. It appears to be a rather inefficient vector but could carry the lettuce-mosaic virus from prickly lettuce, *Lactuca scariola* L., but not from sow thistle, *Sonchus oleraceus* L., which has been reported not to become infected with lettuce-mosaic virus.

One of the nonvectors shown in table 1, the brown ambrosia aphid, breeds on many composites, especially ragweed, and has been found breeding on cultivated lettuce in Texas and Sinaloa, but not in California, even though California specimens of this species reproduced fairly well when confined to young lettuce in the greenhouse.

FLYING APHID POPULATIONS.—Sticky traps were maintained through two winter seasons (1953–54 and 1954–55) from about September 1 to March 31 in one desert and one coastal district. The desert area was the Imperial Valley, Imperial County, and the coastal area was the Oxnard plain, Ventura County. Lettuce mosaic virus usually spreads slowly, if at all, in the Imperial Valley during the lettuce-growing season, whereas it often spreads rapidly and causes severe damage to lettuce on the Oxnard plain.

Fifty-one species of aphids were identified from the two districts, 22 from the desert and 45 from the coast. Two of these species, the cabbage aphid, *Brevicoryne brassicae* (L.), and the chrysanthemum aphid, *Macrosiphoniella sanborni* (Gill.), were reported by Fry (1952) to be nonvectors of lettuce mosaic.

Raw data from the sticky trap catches in each district were added and then divided by the number of traps used in the district to get the average catch per trap for the period of exposure. This figure was then multiplied by a factor obtained as follows. The trap was assumed to have caught four times the number of aphids that were passing through an equal area of free air, a figure obtained by Dickson *et al.* (1956) in their work with citrus aphids. It was also assumed that flying aphids were present at a constant density to the height of 50 ft. and that none were above this height. These were calculated in and a factor obtained which, when multiplied by the average catch per trap, showed the number of aphids passing a mile front. It is not known that the traps caught aphids from four times their area but they did show some attractiveness. It is certain that flying aphids were in the air far above 50 ft. but at a density that diminished with increasing height.

Some of the catches shown are low because wind storms coated traps with sand from time to time, particularly on the desert. The data are shown in this form because it avoids fractions and because it gives a reasonably accurate count of the number of aphids flying in each district. The figures shown are probably low.

In table 2 flying aphid populations are shown by months through the two seasons. Efficient vector species are grouped in one column and inefficient vectors in another. All other aphids, both nonvectors and untested species, are shown in the third column. Population-wise, the greater part of the aphids shown in the third column have been shown to be nonvectors.

For every month shown the total flying aphid population was higher in the desert than on the coast, about 12 times as high on the average. The important point was the identity of the aphids flying in the two locations during the lettuce-growing seasons. The efficient vectors, principally the green peach aphid, were absent or virtually so on the desert during the fall and early winter months while the lettuce crop was being grown there. The high spring population of green peach aphids on the desert, mostly near or after the end of the lettuce season, produced a figure about 2.3 times as high on the desert as on the coast for the total population through the two 7-month periods. On the coast these efficient vectors were shown to be present every month sampled.

On the desert the reverse was true for the inefficient vectors, principally the melon aphid. These were present in large numbers in the fall, especially in 1953, but were almost absent in the winter and early spring.

On the desert the fall populations consisted almost entirely of four species: melon aphid, cowpea aphid (*Aphis medicaginis* Koch), mealy plum aphid (*Hyalopterus pruni* (Geoff.)), and corn leaf aphid (*Rhopalosiphum maidis* (Fitch)). All these species became less numerous in the winter and, except for the melon aphid, increased again in the spring. In January they were joined by the green peach aphid, the cabbage aphid, and some other less numerous species. The four species found in large numbers in the fall are aphids that are able to build to high populations in the late summer even though the temperature is still high. The green peach aphid and the cabbage aphid become either extinct or very rare in the desert during the summer. That they may have to re-enter the area each fall is shown by the observation that one year the cabbage aphid did not appear in the Palo Verde Valley, farther out in the desert, even though broccoli was grown that winter. The data show that one year the green peach aphid was present in November even though the flying population did not begin to rise much until late February. Temperatures in October were favorable for the green peach aphid so that if it was present at that time it must have been rare.

The relatively high figure shown for "other aphids" on the desert in March, 1955, came mostly from an outbreak

Table 2.—Aphids passing a 1-mile front each month in desert and coastal districts.[a]

Year	Month	Desert			Coastal		
		Efficient Vectors[b]	Inefficient Vectors[c]	Other Aphids	Efficient Vectors[b]	Inefficient Vectors[c]	Other Aphids
1953	Sept.	0	5,417,280	98,081,280	2,971,901	153,014	12,584,659
	Oct.	0	22,591,008	123,647,040	250,906	50,371	2,192,573
	Nov.	0	5,502,820	11,599,880	206,237	111,197	2,509,056
	Dec.	0	912,380	10,444,896	28,512	4,752	614,909
1954	Jan.	342,140	38,020	4,419,360	871,517	23,760	2,309,472
	Feb.	2,946,240	0	8,125,920	1,379,030	0	2,426,371
	Mar.	13,258,080	0	35,649,504	1,927,411	0	2,241,043
1954	Sept.	0	1,891,296	42,587,424	246,154	122,602	3,662,842
	Oct.	0	465,696	31,087,584	140,659	11,405	1,438,906
	Nov.	38,016	1,577,664	5,208,192	238,749	12,355	843,005
	Dec.	0	1,824,768	10,815,552	142,560	0	590,198
1955	Jan.	38,016	0	3,050,784	20,909	0	264,211
	Feb.	95,040	0	1,245,024	214,790	62,726	309,830
	Mar.	3,193,344	0	49,800,960	226,195	21,859	1,008,374

[a] Data from sticky traps calculated as explained in text.
[b] *Myzus persicae, Macrosiphum solanifolii, M. barri.*
[c] *Aphis gossypii, Amphorophora sonchi.*

of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), which had been found for the first time in California the previous June. Trap records through March, 1954, do not show this species.

On the coast there is much less seasonal fluctuation of various aphid species than on the desert. The coastal climate is rather constant so that aphid species tend to persist throughout the year. The continued presence of various aphid species tends to maintain a constant population of parasites and predators. Despite them, vector aphid species may reach population levels high enough to cause crop damage by spreading plant viruses.

In both districts studied aphid populations were much higher during the 1953–54 season than during the following year.

Mosaic Incidence and Vector Populations.—In the irrigated desert district studied lettuce is ordinarily planted from about September 1 to December 1. In the coastal district it is planted from August 1 to February. During the seasons studied there was no measurable spread of lettuce-mosaic virus on the desert. One to three per cent seed-borne mosaic appeared in the seedling stage, much of this was removed by thinning, and no measurable buildup appeared later. In the coastal district late summer lettuce received considerable damage from mosaic infection (50% or more) in 1953, as would be expected from the high population of efficient vectors shown in September of that year. Spread was slow during the winter but the following spring there was a severe outbreak based on the rather high vector populations and on the ready availability of diseased lettuce plants, many of them in fields harvested but not yet plowed under.

From these population studies it would appear that when only inefficient vectors were present, spread of lettuce mosaic did not occur. The species for which this is shown is the melon aphid, which built up to a large population on cotton in the desert in the fall of 1953 and was again present in fairly good numbers in the fall of 1954. Data presented in table 1 show that in the laboratory the melon aphid was about one-quarter as efficient as the green peach aphid in the transmission of the lettuce-mosaic virus. If this same ratio had carried over to the field the melon aphid population should have transmitted as much lettuce-mosaic virus as a green peach aphid population one-quarter as large. The population of 22 million melon aphids would then have been equal to a population of $5\frac{1}{2}$ million green peach aphids and there should have been a considerable spread from the 1 to 3% of the plants with seed-borne mosaic. This transmission did not take place. Since we do not know why spread did not occur we can only speculate that the flight or feeding pattern of the melon aphid is such that they do not make successive feedings on lettuce plants in the field, as it is necessary for a vector to do. It is not possible to draw any conclusions as to the role of inefficient vectors in the spread of lettuce mosaic in the coastal district.

Broadbent (1952) reported that in the Thames River Valley the green peach aphid was the most important vector of lettuce mosaic. The alate green peach aphid is a nervous animal, seldom remaining in one spot after her initial flight even on preferred host plants. Young are usually left one to three in a place, unlike some other aphids whose alatae commonly settle down on a plant and remain while their young settle about them. The potato aphid sometimes builds a high population on lettuce and when this occurs it probably becomes an important vector. The lettuce seed-stem aphid is probably of importance only on lettuce grown for seed. As Grogan *et al.* (1952) pointed out, in the desert the high spring population of green peach aphids also can infect lettuce fields left for seed even though fields harvested for heads had received no damage from mosaic. It would appear that under our conditions the green peach aphid is much the most important vector of the lettuce-mosaic virus.

References Cited

Ainsworth, G. C., and L. Ogilvie. 1939. Lettuce mosaic. Ann. Appl. Biol. **26**(2): 279–97.

Borner, Carl. 1952. Europae centralis aphides. Thuringischen Botanischen Gesellschaft. Heft 4 and Mitteilungen. Beiheft **3**: 1–484.

Broadbent, L., T. W. Tinsley, W. Buddin, and E. T. Roberts. 1951. The spread of lettuce mosaic in the field. Ann. Appl. Biol. **38**(3): 689–706.

Dickson, R. C., Metta McD. Johnson, R. A. Flock, and Edward F. Laird, Jr. 1956. Flying aphid populations in southern California citrus groves and their relation to the transmission of the tristeza virus. Phytopath. 46(4): 204–10.

Fry, P. R. 1952. Lettuce mosaic. New Zealand Jour. Sci. and Technol. Sec. A **33**(5): 52–63.

Grogan, R. G., J. E. Welch, and Roy Bardin. 1952. Common lettuce mosaic and its control by the use of mosaic-free seed. Phytopath. **42**(10): 573–8.

Jagger, I. C. 1921. A transmissible mosaic disease of lettuce. Jour. Agric. Res. **20**(10): 737–40.

Lange, W. H., L. C. Benson, D. C. Force, A. A. Grigarick, and N. F. McCalley. 1957. Lettuce root aphid. Calif. Agric. **11**(5): 7, 8, 15.

Newhall, A. G. 1923. Seed transmission of lettuce mosaic. Phytopath. **13**(2): 104–6.

Palmer, Miriam A. 1952. Aphids of the Rocky Mountain region. The Thomas Say Foundation, Vol. **V**: 1–452.

Patch, Edith M. 1938. Food-plant catalogue of the aphids of the world. Maine Agric. Expt. Sta. Bull. **393**: 35–431.

Control and Prevention of Mites in Granary and Rice Weevil Cultures[1]

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ABSTRACT

Laboratory cultures of the granary weevil, *Sitophilus granarius* (L.), and the rice weevil, *Sitophilus oryza* (L.), were invaded by mites of two genera, *Typhlodromus* and *Acaropsis*. Several acaricides were tested for the purpose of eliminating mites from rearing and testing areas of the laboratory without causing undue harm to insects in cultures. Methods are described for the use of Kelthane and Chlorobenzilate to eradicate mites in rearing and testing areas of a stored-product insects laboratory, the use of Kelthane for the control of mites in weevil cultures, and for the prevention of new infestations.

Invasion of insect cultures by nonparasitic mites merely creates a nuisance, but the presence of parasitic mites in laboratory cultures most often leads to serious consequences. The universal nature of this problem is obvious from Mulla's reference (1958) to numerous instances of infestations and reports on methods for the control of mites in cultures of several species of insects.

Weevil cultures maintained by the authors for control investigations were plagued with mites twice within one year. First an infestation of mites (*Typhlodromus* sp.[2]) was found in cultures of the granary weevil, *Sitophilus granarius* (L.). Diligent sterilization of grain for culture media and the use of parent weevils from mite-free cultures readily eliminated the pests, but preliminary chemical control tests were made as a matter of course. Later, a more serious invasion of mites (*Acaropsis* sp.[3]) occurred. Cultures of the granary weevil were almost destroyed, and those of the rice weevil, *Sitophilus oryza* (L.), were seriously harmed. The population of *Acaropsis* mites became so dense in some cultures that mites literally swarmed to surrounding areas. Test samples of insect species originating from uninfested cultures, especially larvae of the khapra beetle, *Trogoderma granarium* Everts, were destroyed when placed on mite-contaminated laboratory shelves. Thus, the elimination of mites from rearing and testing areas of the laboratory and the development of safe measures for the prevention of mite infestations in stored-product insect cultures became an urgent task.

It is the purpose of this paper to present results from a series of tests with acaricides which led to a useful method of eliminating mites in granary and rice weevil cultures and to practical preventive measures. Finally, the use of Kelthane and Chlorobenzilate for the eradication of mites in rearing and testing areas, control of mites in cultures, and the prevention of new infestations are discussed.

ACARICIDES TESTED.—The five acaricides and formulations used were as follows: Aramite—15% wettable powder; Chlorobenzilate—25% wettable powder and 25% emulsifiable concentrate; Kelthane—18.5% wettable powder and 18.5% emulsifiable concentrate; ovex—50% wettable powder; Tedion—25% wettable powder.

PRELIMINARY TESTS FOR TYPHLODROMUS MITE CONTROL.—*Procedure.*—The laboratory method developed by Krantz (1956) for testing protectants against the grain mite was followed with minor modifications. Using 27 ×98 mm. glass vials for test containers, tests were set up in the following manner. A small piece of water-saturated dental absorbent roll was placed at the bottom of each vial. Clean whole wheat flour was sifted gently into control vials to a depth of 62½ mm. and to a depth of 50 mm. in vials intended for acaricide treatments. An additional 12½ mm. of flour containing acaricides in proportions listed in table 1 was sifted into the latter vials. The acaricide-flour mixtures with the desired p.p.m. of acaricides (see table 1) were obtained by blending wettable powder formulations of acaricides and whole wheat flour with a mixing wheel as described by Gunther *et al.* (1958). Several hundred mites were introduced into each vial, and a ring of petrolatum was placed about 30 mm. above the flour to prevent movement of mites out of the test vials. All treatments were replicated five times in randomized complete blocks. Test samples were held at 80° F. ±2° and 70% R. H. (relative humidity) for 14 days. Then

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[2] Identified by Dr. Edward W. Baker, Entomology Research Division, Agricultural Research Service, U. S. Department of Agriculture, Washington, D. C.

[3] Identified by Dr. Irwin N. Newell, Division of Life Sciences, University of California, Riverside.

Table 1.—Effectiveness of five acaricides at various concentrations in preventing *Typhlodromus* mite penetration into flour as measured by an index of mite activity[a] and summarized in index means for five replications.

Acaricide	P.p.m. of Acaricide in Whole Wheat Flour								
	0	10	25	50	75	100	200	500	1000
Aramite	2.2	1.6	1.8	2.4	2.8	2.2	3.3	3.0	3.0
Chlorobenzilate	1.8	2.5	3.0	3.2	4.0	4.2	3.6	4.6	4.8
Tedion	1.8	1.8	2.0	2.5	2.8	2.8	3.0	3.5	3.8
Ovex	2.0	2.4	3.4	3.4	3.2	4.2	3.8	4.2	4.8
Kelthane	1.6	2.6	2.6	3.4	4.0	4.2	4.6	5.0	5.0

[a] The index of mite activity is based on relative degrees of penetration into flour as follows:

1. Complete pattern of mite trails throughout treated and untreated flour.
2. Complete pattern throughout treated flour with some movement into untreated flour.
3. Complete pattern only in treated flour with little or no penetration into untreated flour.
4. Sparse pattern in treated flour only.
5. At most, minute penetration into surface of treated flour.

test vials were examined and indexed by Krantz's index of mite activity (1956) based on mite penetration into flour.

Results.—A summary of results from preliminary tests with acaricides for the control of *Typhlodromus* mites is given in table 1. Under the conditions of the experiment, the data presented suggest that effectiveness was in the order of Kelthane, Chlorobenzilate, ovex, Tedion, and Aramite.

Effect of Residual Surface Treatments with Acaricides on Granary and Rice Weevils.—*Procedure.*—The inside of petri dishes, tops and bottoms, was sprayed with 1.0% wettable powder suspensions of acaricides listed in table 2. Immediately after spraying, treated dishes were inverted over racks and allowed to dry for 2 hours. After drying, approximately 3 gms. of untreated wheat and 25 weevils were placed in each petri dish and held at 80° F. and 50% R. H. for 7 days before recording mortalities of test insects. Treatments were replicated six times for each insect species.

Results.—The toxic effect of residual surface treatments with five acaricides on granary and rice weevils is shown in table 2. The variations between acaricides in toxicity and between species in susceptibility is readily seen. The range in toxicity from the nontoxic Aramite to the 100% mortalities resulting from Tedion indicated that acaricides used for the control and prevention of mites in weevil cultures must be handled with considerable discretion.

Use of Acaricides in Water When Adjusting the Moisture Content of Wheat for Culture Media.—As the moisture content of wheat for weevil cultures was systematically adjusted to 14% by the addition of water, it appeared logical to conduct an experiment in which known dosages of acaricides were included in the water to give protection against mites. Other than the addition of acaricides and the deliberate infestation of test cultures with mites, no changes were made in culture techniques existing at that time. Details as to procedure and results of the experiment follow.

Procedure.—Wheat was sterilized at −10° F. for 7 days, then divided into test lots of 1600 gms. each and placed in tightly covered 1-gallon wide-mouth jars. The amounts of Chlorobenzilate, ovex, and Kelthane wettable powders needed to obtain the desired dosages of acaricides (0, 100, 200, and 500 p.p.m.) were added to water used to increase

Table 2.—Effect of residual surface treatments with acaricides on granary and rice weevils after an exposure period of 7 days in the presence of food.

Acaricide	Mean Percentage of Insect Mortality	
	Granary Weevils	Rice Weevils
Aramite	9.3	0.6
Chlorobenzilate	33.3	49.3
Kelthane	51.3	82.7
Ovex	54.0	8.0
Tedion	100.0	100.0
Check	9.3	0.0

the moisture content of each lot of wheat from 10.3% to 14.0%. After moisture adjustment, wheat was tempered at 50° F. for 7 days.

Each lot of tempered test-wheat was divided into 400-gm. samples and placed in 1-quart culture jars. Two of the four samples from each lot (two replications) were for cultures of granary weevil and two for rice weevils. A liberal supply of *Typhlodromus* mites, approximately one-half teaspoonful of mites and debris screened from a heavily infested weevil culture, was placed into each 1-quart culture jar. Granary and rice weevils, 200 of each species per test-culture replication, were introduced into their separate containers. After an egg deposition period of 1 week, the wheat was screened to remove parent weevils, and adult mortalities were recorded. The screened wheat was returned to culture jars and held for an additional 7 weeks before rating mite infestations and recording the number of adult weevils which had emerged in test cultures.

Experimental cultures were held at 80° F., but the humidity could not be controlled. However, a small amount of water was added to each culture at 14-day intervals to provide sufficient moisture for the development of insects and mites.

Results.—Three criteria considered essential for the proper interpretation of results from the use of acaricides in water when adjusting the moisture content of wheat for weevil culture media were: (1) the toxicity of treatments to parent weevils during the 7-day egg-deposition period, (2) the number of weevils present in cultures after a normal developmental period, and (3) the effectiveness of treatments in eliminating mites from new cultures. Summaries of results from data collected for each criterion are given in tables 3, 4, and 5. The data presented indicate that under the conditions of the experiment effective dosages of acaricides for the elimination of mites are deleterious to weevil cultures.

Table 3.—Mean percentages of mortality in parent granary and rice weevils after an exposure period of 7 days to various acaricide treatments applied as wettable powder suspensions when adding water to increase the moisture content of wheat for use as culture media.

Acaricide	Mean Percentage Mortality							
	Granary Weevils				Rice Weevils			
	0[a]	100	200	500	0	100	200	500
Chlorobenzilate	2.3	1.8	19.6	60.8	1.0	2.5	3.5	34.8
Ovex	0.8	1.5	5.3	23.3	2.3	1.5	2.3	8.5
Kelthane	0.5	5.5	17.5	47.5	2.5	6.8	42.8	63.5

[a] Dosages of acaricides in p.p.m.

Table 4.—Mean numbers of granary and rice weevils from acaricide-treated culture media after a developmental period of 8 weeks from the time of initial introduction of parent weevils onto wheat for egg deposition.

	Mean Number of Live Weevils							
	Granary				Rice			
Acaricide	0[a]	100	200	500	0	100	200	500
Chlorobenzilate	613	575	185	30	825	1075	1655	1233
Ovex	530	790	438	275	1293	1330	1430	1350
Kelthane	445	425	217	58	1190	386	324	195

[a] Dosages of acaricide in p.p.m.

Use of Kelthane for Mite Control and Prevention without Injury to Granary and Rice Weevil Cultures.—In preliminary tests for the control of *Typhlodromus* mites, Kelthane appeared to be the most effective material used (tables 1 and 5). The results given in tables 2, 3, and 4, however, suggested considerable toxicity to weevils by Kelthane as indicated by weevil mortalities and reproduction. It was obvious that caution must be exercised in the use of Kelthane for the eradication and subsequent prevention of mites in cultures of granary and rice weevils. For this reason, an experiment was conducted in an attempt to find methods of using Kelthane with the least injury to weevil cultures.

Procedure.—Approximately 1,000 granary weevils were placed on each of 12 samples of wheat (14% moisture content) weighing 1,200 gms. per sample and held for 7 days, the usual time allotted to egg laying in weevil cultures maintained in this laboratory. Rice weevils were handled in the same manner as granary weevils. After the 7-day egg-deposition period, parent weevils were screened from wheat. Then each sample of wheat was divided into four subsamples (one for each treatment) with a precision divider and placed in 1-quart culture jars. This permitted 12 replications for each of the following treatments.

1. Control—no Kelthane was used.
2. Culture jars were covered with Kelthane-treated cloths. (Cloth for covering jars was soaked in 18.5% Kelthane emulsifiable concentrate and dried before use on culture jars.)
3. Two grams of 18.5% Kelthane wettable powder per replicate was thoroughly mixed with the wheat in 1-quart culture jars and left for 24 hours. Then the treated wheat was screened and cleaned twice with a laboratory aspirator used for cleaning seed. Culture jars were covered with Kelthane-treated cloths as in No. 2.
4. Same as No. 3 except that after cleaning wheat with the laboratory aspirator it was washed to remove any Kelthane wettable powder adhering to wheat kernels, then dried for 16 hours with a warm blast of air in a mechanical convection oven.

Test cultures were held for weevil development at 80° F. and 55 to 65% R. H. The numbers of live weevils were tabulated at the end of 6 and 8 weeks following initial egg deposition for rice weevils and at the end of 7 and 9 weeks for granary weevils.

Results.—The data presented in table 6 indicate that Kelthane may be used for the eradication and prevention of mites in cultures of granary and rice weevils without serious injury to the insects. Treatments Nos. 3 and 4 were viewed primarily for mite eradication in cultures.

Table 5.—Effectiveness of three acaricides at various dosage levels in eliminating *Typhlodromus* mites from granary and rice weevil cultures as measured by ratings[a] used to indicate the degree of mite activity in test cultures.

	Mean Rating for Mite Activity			
	(Dosage of Acaricide in P.p.m.)			
Acaricide	0	100	200	500
Chlorobenzilate	1.00	1.25	1.75	2.50
Ovex	1.00	1.00	1.00	1.25
Kelthane	1.00	2.25	3.00	4.00

[a] Rating of test culture for mite activity:
1. Heavy—masses of mites, inside and outside of culture jars.
2. Medium—mites conspicuous, wheat almost covered.
3. Light—a few mites observed, wheat bright.
4. None—no mites seen, wheat bright.

The decrease in the mean number of live weevils from the first count to the second in Treatment No. 3 indicated that sufficient Kelthane to be harmful to emerging insects remained in the cultures. An increase in the mean number of weevils in Treatment No. 4 for the same period suggested that Kelthane had been removed from wheat by washing and was not causing injury to insects emerging in cultures. Unfortunately, wheat was over-dried in Treatment No. 4, and this was considered the reason for the low numbers of weevils emerging in cultures. The use of Kelthane-treated cloths in Treatment No. 2 to cover culture jars had no obvious effect on the weevil population in test cultures.

The Use of Kelthane and Chlorobenzilate to Eradicate Mites in Rearing and Testing Areas, the Control of Mites in Weevil Cultures, and the Prevention of New Infestations.—An *Acaropsis* mite invasion into weevil cultures demanded immediate attention, and the urgent nature of the problem did not favor more extensive investigation than the few preliminary experiments reported in this paper. Steps taken to solve the problem, however, were based on the evidence available. These are briefly outlined.

1. All cultures and test material were removed from rearing and testing areas of the laboratory. These areas were thoroughly sprayed with a 1:1 mixture of undiluted Kelthane and Chlorobenzilate emulsifiable concentrates. After aeration for 2 days, all shelves used for rearing and testing were covered with cloths which had been soaked in 18.5% Kelthane emulsifiable concentrate and dried before use in the laboratory.

Table 6.—Mean number of live granary and rice weevils per culture after using Kelthane in various ways for mite control and prevention in weevil cultures.

	Mean Number of Live Insects			
	Granary Weevils		Rice Weevils	
Kelthane, Treatment No.	7 Weeks[a]	9 Weeks	6 Weeks	8 Weeks
1	603	1107	1800	2192
2	677	1189	1733	2158
3	298	243	1296	675
4	150	358	600	800

[a] Time after initial egg deposition.

2. Cultures other than those of the granary and rice weevils were covered with Kelthane-treated cloths and returned to the rearing area of the laboratory.

3. Granary and rice weevil cultures with only developmental stages present were treated as follows: A liberal amount of 18.5% Kelthane wettable powder was mixed with the wheat in each culture jar and left for 24 hours. Then the wheat was screened to remove as much Kelthane as possible, cleaned twice with a laboratory aspirator, washed thoroughly over screens, then spread to dry overnight. When dry, the wheat was placed in clean culture jars which were covered with Kelthane-treated cloths and returned to the rearing room.

4. The more heavily infested granary and rice weevil cultures with adult insects present were destroyed; the others were covered with Kelthane-treated cloths and returned to the rearing room.

5. After removing parent weevils from new cultures, Step 3 was followed until mite-free cultures were available for parent weevils.

The steps taken to eradicate mites were successful as evidenced by the lack of a mite infestation in this laboratory for several months. However, as a preventive measure, Kelthane-treated cloths are used on all laboratory cultures of stored-products insects.

Whether insects do or do not show increased resistance to insecticides after the use of an acaricide such as Kelthane to eliminate mites from cultures was not determined.

REFERENCES CITED

Gunther, F. A., *et al.* 1958. Relation of structure of diphenylmethane derivatives to toxicity to *Tribolium confusum* Duv. Jour. Econ. Ent. **51**(3): 385–90.

Krantz, Gerald W. 1956. A laboratory method for testing grain protectants against the grain mite. Jour. Econ. Ent. **49**(6): 813–4.

Mulla, Mir S. 1958. Control of mites in laboratory cultures of the eye gnat, *Hippelates collusor* (Townsend). Jour. Econ. Ent. **51**(4): 461–2.

Feeding Polybor 3 for Fly Control under Caged Layers[1]

EDWARD C. BURNS, B. A. TOWER, F. L. BONNER, and H. C. AUSTIN[2]

ABSTRACT

Polybor 3 (containing 98% of disodium octaborate tetrahydrate ($Na_2B_8O_{13} \cdot 4H_2O$)) was fed to caged layers 5 months at 0.05, 0.10, 0.20, 0.30, and 0.50% of the ration. Effective larval control of the house fly (*Musca domestica* L.) was obtained at the higher rates of feeding, but boron residues were found in both eggs and tissues at all levels.

One of the greatest problems associated with caged layer production is house fly control. Specked or dirty eggs resulting from heavy adult fly populations must be cleaned and washed before marketing. Heavy larval infestations cause liquefaction of the droppings thus preventing coning and drying of the manure. Wet, soupy spots often are found in houses even when adult flies are at a minimum. This is often noted when baits or strings are used for adult fly control. Under such conditions, a persistent insecticide applied to the droppings would seem to be indicated. Unfortunately, steady accumulation of the droppings necessitates repeated application of insecticide. An even better solution would be the incorporation of an inert insecticide into the ration which would be excreted in the droppings. Recent studies by Quisenberry *et al.* (1958) indicating that larval control can be achieved in the droppings by low level feeding of Polybor 3[3] in the rations of caged layers seems to be a step in this direction. Since McGovran & Piquett (1945) have reported a 50% kill of house fly maggots in larval media to which 924 p.p.m. of borax had been added, further investigations were undertaken to determine if larval control could be obtained by feeding Polybor 3 in the ration at levels which would not result in boron residues in the eggs or tissues of the birds.

MATERIALS AND METHODS.—Twenty-four commercial hybrid hens were brought into the laboratory in early November, 1957 where the temperature was held around 80° F. The birds were weighed and then placed in a battery where they were separated into four groups or blocks with each block consisting of five treatments and a check. As shown in figure 1, the battery was designed to provide individual feed troughs and dropping pans. Continuous lighting was provided by suspending a 60-watt bulb about 4 feet above the birds at each end of the battery. Polybor 3 was fed in the ration at 0, 1, 2, 4, 6 and 10 pounds per ton or 0.0, 0.05, 0.1, 0.2, 0.3, and 0.5% in the ration. Oyster shell and grit were given free choice. Treatment was started 1 week after the birds were placed in the cages. Daily records were kept of egg production and eggs were held under refrigeration until boron analyses could be made. At the completion of the experiment, the hens were removed from the cages, weighed, and sacrificed and tissues were analyzed for boron content.

Boron was determined on egg contents, poultry tissue and feces samples using the simplified curcumin procedure of Dible *et al.* (1954). Minor modifications of sample preparation were necessary to adapt the method to the particular material being analyzed. Homogeneous samples of yolk and albumin were prepared by blending samples for 1 minute in a Waring Blendor. Suitable aliquots (5 ml.) were transferred with pipettes to platinum dishes and weighed. Feces were dried at 100° C. to obtain percentage moisture and produce an easily handled sample. The material was ground in a mortar, weighed into a platinum dish and moistened with a few ml. of distilled water. Tissue was minched and weighed into platinum dishes. Anhydrous sodium carbonate (0.5 gram) was added to all samples and after mixing, they were dried

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[3] Supplied by Pacific Coast Borax Co., Los Angeles, California.

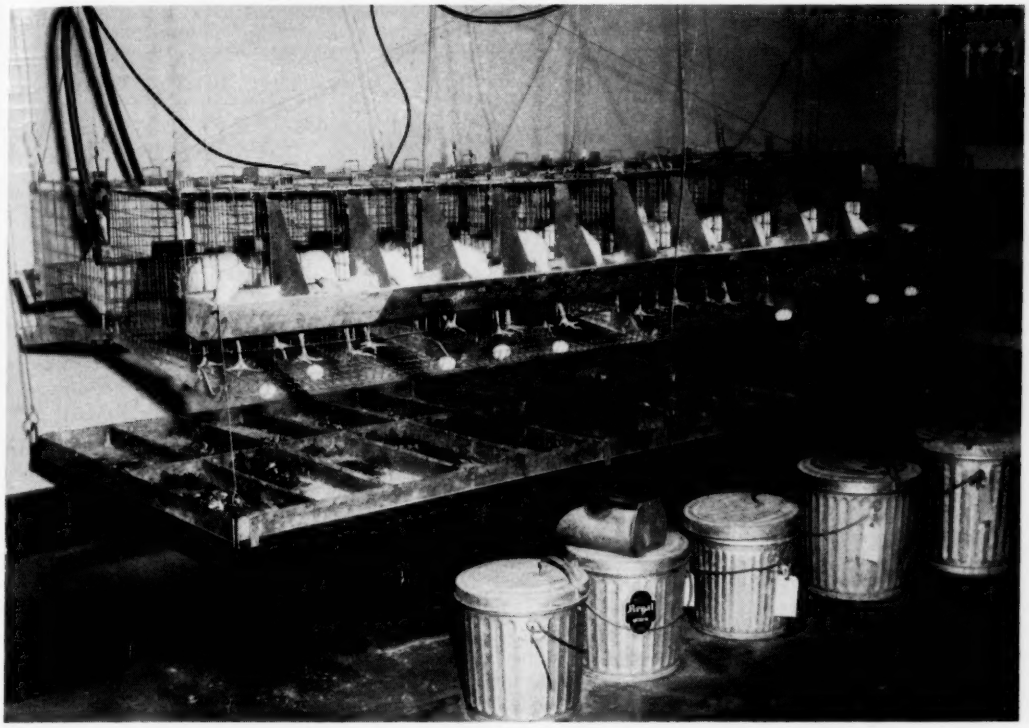

FIG. 1.—Caged layer installation for individual feeding and droppings collection.

overnight at 100° C., then ashed for one hour at 600° C. The samples were allowed to cool and the residue dissolved in 5 ml. 0.1N HCl, then transferred quantitatively to a screw capped polyethylene bottle and made up to 25 ml. with distilled water. After shaking thoroughly and allowing to settle, a suitable aliquot was used for the determination of boron. Using the established method and sample preparation as given, the average per cent recovery was 98.66. All boron analyses are reported on the original moisture basis.

The laboratory in which the birds were kept was maintained free of flies by mechanical means and through periodic cleaning of the dropping pans. Droppings were allowed to accumulate in the pans approximately 1 week before larval control studies were begun. The droppings then were removed from the pans and 100 house fly eggs from the Orlando Florida susceptible strain were brought in and introduced onto the droppings. The droppings were held in screened cages and the treatments were evaluated by counting the adults that emerged. Since possible accumulation of boron in the eggs and tissues over an extended feeding period was of interest the test was continued long enough to allow larval control studies to be made December 17, January 7, and March 5.

RESULTS AND DISCUSSION.—The results of the larval control studies are shown in table 1. Analysis of variance of the data showed that differences among Polybor 3 treatments and between treatments and checks were significant at the 1% level. Differences among dates and treatments time dates also were significant at the 1% level, and the interaction between treatments and dates was significant at the 1% level. The holding method used for the larvae in the last two dates was different from that used at first. In these cases droppings were held in 1-gallon ice cream cartons with screened tops and bagasse pupation media instead of the completely screened cages and sand pupation media as used in the first test. Although effective control of larvae was obtained with the higher levels of Polybor 3, adverse effects were noted in egg size and production as well as feed consumption, Tower *et al.* (Unpublished).

Total boron was determined on egg contents from each level of treatment at weekly intervals for 15 consecutive weeks. The boron content of eggs increased in proportion to the percent of Polybor 3 in the rations. Bertrand & Agulhon (1913) reported that normally eggs did not contain more than 0.1 p.p.m. of boric acid (equivalent to 0.02 p.p.m. boron); however, analysis of two lots of "normal" eggs gave values of 0.2 and 0.3 p.p.m. boron. Eggs from the untreated ration averaged 0.3 p.p.m. boron dur-

Table 1.—House fly emergence from poultry droppings following continuous feeding of Polybor 3 to caged layers.

PER CENT POLYBOR 3 IN FEED[a]	AVERAGE PER CENT EMERGENCE		
	Dec. 17	Jan. 7	Mar. 5
0.00	60	21	57
.05	66	30	34
.10	69	23	25
.20	21	9	9
.30	1	4	1
.50	0	0	0

[a] Treatment began November 12, 1957.

Table 2.—Boron content of eggs and feces following continuous feeding of Polybor 3 to caged layers.

Sampling Date 1957–58	Week	Per Cent Polybor 3 in Ration					
		0	0.05	0.1	0.2	0.3	0.5
		Boron in eggs (p.p.m.)					
11/14–11/20	1st	0.6	1.6	2.5	4.6	7.0	11.5
11/21–11/27	2nd	.4	1.7	2.7	10.0	10.2	15.3
11/28–12/4	3rd	.4	1.9	4.2	12.3	12.7	16.6
12/5 –12/11	4th	.4	2.3	5.4	12.2	13.1	17.7
12/12–12/18	5th	.1	2.4	4.0	8.3	10.9	14.8
12/19–12/25	6th	.2	1.6	2.9	8.9	10.9	13.8
12/26– 1/1	7th	.0	0.8	2.4	7.5	9.3	12.4
1/2 – 1/8	8th	.5	1.6	3.5	11.1	12.6	17.3
1/9 – 1/15	9th	.4	2.3	3.6	8.0	10.6	14.6
1/16– 1/22	10th	.1	1.6	3.3	5.7	7.8	12.9
1/23– 1/29	11th	.1	1.7	2.8	4.4	4.7	8.8
1/30– 2/5	12th	.2	1.7	3.4	6.4	6.7	14.1
2/6 – 2/12	13th	.2	1.3	3.5	7.3	8.2	13.8
2/13– 2/19	14th	.3	1.4	1.9	4.8	5.2	7.8
2/20– 2/26	15th	.0	0.7	0.9	3.2	3.8	8.2
		Boron in Feces[a] *(p.p.m.)*					
2/15	1 day	1.8	12.6	29.8	47.4	37.0	130.4

[a] Samples taken 14th week of trial.

ing the experiment and a sample of water from the communal drinking trough contained 0.5 p.p.m. boron. There is some indication of leveling off or reduction in boron residues with time, particularly at higher rates of feeding. During the 14th week of the experiment samples of feces were taken from all levels of treatment. Normal feces were found to contain 1.8 p.p.m. The results of the determinations on egg and feces samples are reported in table 2.

Little residue was found in the tissues following 148 days of feeding Polybor 3 except at the highest levels of feeding, table 3. This would seem to indicate that boron is excreted rapidly by the birds. The muscle and body fat tissue were composited, therefore it is impossible to know in which tissue the residue was higher.

Table 3.—Boron content of poultry tissues after feeding Polybor 3 148 days.

Per Cent Polybor 3 in Feed	Boron in Tissues (p.p.m.)			
	Liver	Brain	Kidney	Breast Muscle+Fat
0.00	0.0	0.3	1.9	1.0
.05	0.9	0.0	1.1	1.1
.10	2.5	0.0	0.8	0.1
.20	1.4	1.1	4.2	3.4
.30	0.0	2.8	1.2	4.9
.50	6.2	8.5	7.3	5.2

Although boron residues in tissues were relatively low, boron compounds are considered poisonous and deleterious substances by the U. S. Food and Drug Administration and their residues in poultry tissues or eggs, in the absence of established tolerances, would render the food adulterated under the Federal Food, Drug and Cosmetic Act.

References Cited

Bertrand, G., and H. Agulhon. 1913. Recherches sur la presence du bore dans le lait et dans les oeufs; par MM. Bull. Soc. Chim. **13**: 824–7.

Dible, W. T., Emil Truog, and K. C. Berger. 1954. Boron determination in soils and plants. Analyt. Chem. **26**: 418–21.

McGovran, E. R., and P. G. Piquett. 1945. Toxicity of benzene hexachloride to house fly larvae. Jour. Econ. Ent. **38**(6): 719.

Quisenberry, J. H., C. B. Ryan, and M. A. Price. 1958. Chemicals in the laying ration as a means of fly control with particular reference to laying cages. Paper presented at Association of Southern Agricultural Workers Meeting.

Tower, B. A., E. C. Burns, H. C. Austin, and F. L. Bonner. The performance of caged layers fed varying percentages of borax (Polybor 3) in the ration. (In manuscript.)

Effects of Gamma Radiation on Some Insects Affecting Man[1]

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Abstract

The LD-50 of gamma radiation from cobalt-60 against the body louse (*Pediculus humanus humanus* L.), house fly (*Musca domestica* L.), American cockroach (*Periplaneta americana* (L.)), German cockroach (*Blattella germanica* (L.)), firebrat (*Thermobia domestica* (Pack.)), bed bug (*Cimex lectularius* L.), and Pharaoh ant (*Monomorium pharaonis* (L.)) ranged from 130 r for half-day-old house fly eggs to 190,000 r for body louse nymphs and Pharaoh ant queens. Doses required to cause 100% mortality ranged from 600 r to 250,000 r. Among the species tested, the LD-50 varied inversely with the size of the insect. Reproduction in body lice was inhibited at dosages of 75,000 r or higher. DDT-resistant body lice were as susceptible to gamma rays as non-DDT-resistant lice.

The increasing availability of radioactive materials and skill in their commercial utilization brightens the prospect of their use for the control of certain insect pests. It has been known for many years that insects can be killed with X-rays, but this source of radiation is expensive and has been primarily used for genetic studies. Has-

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[2] The larger capacity source used in these studies was designed and installed by M. E. Jefferson, radiological safety officer, assisted by J. F. Mullins, engineer, Agric. Res. Serv., U.S.D.A., with the cooperation of physicists and engineers of Brookhaven National Laboratory. R. C. Bushland, A. H. Baumhover, F. H. Dudley, and I. H. Gilbert, of the Orlando laboratory, assisted in these studies. Suggestions were also received from T. C. Helvey of the Radiation Biophysics Department, University of Kansas.

Table 1.—Doses of gamma radiation required to cause mortality of various insects in 24 hours.

INSECT AND STAGE OF FORM	AGE (DAYS)	LD-50 (r)	MINIMUM DOSE CAUSING 100% KILL (r)
Body louse:			
Egg	0– 2	<10,000[a]	50,000[a]
	1– 3	<10,000[a]	50,000[a]
	2– 4	24,000[a]	75,000[a]
Nymph	1– 3	190,000	225,000
	4– 6	170,000	250,000
	8–10	170,000	225,000
Male	13–16	170,000	210,000
	18–21	170,000	200,000
Female	13–16	170,000	200,000
	18–21	180,000	200,000
House fly:			
Egg	1/2	130[a]	600[a]
Larva	1– 2	1,300[a]	5,000[a]
	3– 4	1,100[a]	2,000[a]
	5– 6	1,100[a]	2,000[a]
Pupa	1	15,000	35,000
Male	4– 5[b]	72,000	120,000
Female	4– 5	110,000	150,000
American cockroach:			
Nymph	—	28,000	67,500
Male	—	50,000	67,500
Female	—	48,000	67,500
German cockroach:			
Nymph	42–49	70,000	105,000[c]
Male	56–63	76,000	97,500[c]
Female	56–63	72,000	90,000
Firebrat:			
Nymph	—	92,000	127,500[c]
Male	—	98,000	120,000[c]
Female	—	98,000	120,000[c]
Bed bug:			
Nymph	28–35	150,000	172,500[c]
Male	49–56	160,000	180,000
Female	49–56	150,000	180,000
Pharaoh ant:			
Worker	—	140,000	225,000
Queen	—	190,000	210,000

[a] Mortality based on emergence, not necessarily in 24 hours.
[b] Age of flies calculated from date of emergence.
[c] 48-hour mortality; some survival after 24 hours.

sett & Jenkins (1952) reported that 64,400 r of gamma radiation was completely lethal to six species of stored-product insects and 16,000 to 32,000 r inhibited reproduction. They suggested two methods of insect control by this means, fast killing doses of 65,000 r or lower doses to stop reproduction. Sterilization of screw-worm flies with X-rays and gamma rays was reported by Bushland & Hopkins (1951, 1953), and a method for the control of the screw-worm by the release of large numbers of male flies sterilized by gamma ray irradiation proved successful in large-scale field tests (Knipling 1955, Lindquist 1955, and Baumhover *et al.* 1955).

This paper reports the results of experiments conducted at Orlando, Fla., to provide information on the amount of gamma ray irradiation required to kill certain insects affecting man.

MATERIALS AND METHODS.—The insects used were the body louse (*Pediculus humanus humanus* L.), house fly (*Musca domestica* L.), American cockroach (*Periplaneta americana* (L.)), German cockroach (*Blattella germanica* (L.)), firebrat (*Thermobia domestica* (Pack.)), bed bug (*Cimex lectularius* L.), and Pharaoh ant (*Monomorium pharaonis* (L.)). Various ages and stages of the insects, including adults of both sexes, were exposed in paper pill boxes inside a cobalt-60 source. Two radiation sources were used, one, described by Darden *et al.* was calibrated in polystyrene plastic and had an average dose rate of approximately 400 r per minute over the useful volume. The second unit was designed for higher capacity, having a useful volume of about 2 liters over which the dose rate (air calibration) was approximately 1,000 r per minute. Exposure of body lice was in the larger unit only, the other species being exposed in either or both units. Except during the actual exposure period, the insects were maintained in rooms at constant optimum conditions for each species. Mortality of the motile forms was recorded 24 and 48 hours after exposure; moribund insects were counted as dead. The 48-hour results are not reported for most species, since they were approximately the same as the 24-hour results. Mortality of body louse and house fly eggs and fly pupae was determined several days after exposure when enough time had elapsed for eggs to hatch or adults to emerge from pupae. Mortality of fly eggs was based on larval emergence in a rearing medium and that of pupae on adult emergence. All doses were rounded off owing to the usual error in calibration of the sources. The LD-50's were calculated from log-probit curves.

RESULTS.—The calculated LD-50's, based on the 24-hour mortality except as noted, and the minimum doses that caused 100% mortality in 24 or 48 hours are given in table 1. The LD-50's ranged from 130 r for house fly eggs one-half day old to 190,000 r for body louse nymphs and Pharaoh ant queens. The minimum dose that caused 100% mortality ranged from 600 r for ½-day-old house fly eggs to 250,000 r for 4- to 6-day-old body louse nymphs. It was interesting to find that of the species tested, the larger the insect the lower was the dose required to kill. Additional studies are planned on the relationship of size to susceptibility, with due consideration for such factors as the ratio of skeletal to soft tissue and species differences. The average weights of females of each species and their LD-50's were as follows:

Table 2.—Per cent hatch of eggs from body lice that had been exposed to gamma radiation.

Stage of Lice When Exposed	Age (Days)	Dosage (r)						Unexposed Check
		10,000	50,000	75,000	100,000	125,000	150,000	
First instar	1– 3	71	78	—[a]	—[b]	—[b]	—[c]	91
Second instar	5– 8	82	79	—	—	—[b]	—[c]	91
Third instar	9–12	9	16	—	—	—[a]	—	91
Adult	13–16	0	0	0	0	0	0[a]	91
	22–25	0	0	0	0	0[a]	0[c]	87

[a] All lice dead within 9 days after radiation.
[b] All lice dead within 7 days after radiation.
[c] All lice dead within 6 days after radiation.

Species	*Milligrams*	*LD-50 (r)*
Pharaoh ants	1.20	190,000
Body lice	1.36	180,000
Bed bugs	4.37	150,000
House flies	21.00	110,000
Firebrats	21.28	98,000
German cockroaches	81.77	70,000
American cockroaches	1,148.00	50,000

The viability of eggs produced by body lice irradiated in various stages of development is shown in table 2. No eggs were laid by lice exposed in the nymphal stage at doses of 75,000 r or more. The number of eggs laid by nymphs exposed to lower doses and by adults exposed to all doses ranged from 7 to 101. At 10,000 to 50,000 r lice in each nymphal instar survived to lay eggs; the fertility was reduced to the greatest degree when the irradiation was given in the third instar. Some adults survived all doses from 10,000 r to 150,000 r long enough to lay a few eggs, but none of the eggs hatched.

A highly DDT-resistant strain of body lice, the Korean A colony described by Cole *et al.* (1957), was no more resistant to irradiation from gamma rays than the regular nonresistant strain.

For adequate practical control of body lice a quick-kill dosage for all motile stages would be necessary, since any live lice would be capable of transmitting such diseases as typhus. Therefore, mere inhibition of reproduction would not be satisfactory.

Doses of radiation lower than the 24-hour LD-50 caused complete mortality of body lice over longer periods of time as shown in table 2.

References Cited

Baumhover, A. H., A. J. Graham, B. A. Bitter, D. E. Hopkins, W. D. New, F. H. Dudley, and R. C. Bushland. 1955. Screw-worm control through release of sterilized flies. Jour. Econ. Ent. **48**(4): 462–6.

Bushland, R. C., and D. E. Hopkins. 1951. Experiments with screw-worm flies sterilized by X-rays. Jour. Econ. Ent. **44**(5): 725–31.

Bushland, R. C., and D. E. Hopkins. 1953. Sterilization of screw-worm flies with X-rays and gamma rays. Jour. Econ. Ent. **46**(4): 648–56.

Cole, M. M., M. D. Couch, G. S. Burden, and I. H. Gilbert. 1957. Further studies on resistance of human body lice to insecticides. Jour. Econ. Ent. **50**(5): 556–9.

Darden, E. B., E. Maeyens, and R. C. Bushland. 1954. A gamma-ray source for sterilizing insects. Nucleonics **12**(10): 60–2.

Hassett, C. C., and D. W. Jenkins. 1952. Use of fission products for insect control. Nucleonics **10**(12): 42–6.

Knipling, E. F. 1955. Possibilities of insect control or eradication through the use of sexually sterile males. Jour. Econ. Ent. **48**(4): 459–62.

Lindquist, A. W. 1955. The use of gamma radiation for control or eradication of the screw-worm. Jour. Econ. Ent. **48**(4): 467–9.

OBITUARY

John Edward Dudley, Jr.
1886-1959

John E. Dudley, Jr. was born in Wellesley, Massachusetts on August 28, 1886. He attended the primary school and high school at Wellesley and entered the Massachusetts Agricultural College in September 1908. For the next three years John specialized in entomology and made noteworthy records as a quarter-mile runner on the college relay team. In 1911 he accepted a position as a research entomologist on the Gypsy and Browntail Moth Investigations at Melrose Highlands, Mass. In 1913 he transferred to research on insecticides with the Insecticide and Fungicide Board at Vienna, Virginia. Beginning in 1918 John began his work with the Bureau of Entomology and Plant Quarantine, principally at Madison, Wisconsin and vicinity, where he conducted extensive entomological research for 33 years, up to the time of his retirement on October 31, 1951. He made outstanding contributions to the solution of many problems relating to insects affecting vegetables, particularly on the biology, ecology, and control of the pea aphid, potato leafhopper, striped cucumber beetle, and onion maggot. The results of these and related investigations were included in approximately 50 publications. In addition to his official duties John continued his studies in entomology at the University of Wisconsin, receiving his B.S. degree from that institution in 1926 and his M.S. degree from the same source in 1928.

Soon after his retirement John moved to St. Petersburg, Florida, where he was living at the time of his death on January 24, 1959. He is survived by his wife Frances, of St. Petersburg, whom he married on October 28, 1911; a son, Lt. Comdr. Sherman F. of Washington, D. C.; and a daughter Mrs. John R. Shaw of Madison, Wisconsin.

John was a member of the Entomological Society of America, the former American Association of Economic Entomologists, American Association for the Advancement of Science, the Rotary Club of Madison, Wisconsin, the Masonic Order (32nd degree) and Delta Upsilon and Sigma Xi.

D. J. Caffrey

Soil Applications of Insecticides for Control of Tobacco Thrips on Peanuts[1]

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Abstract

Experiments on control of tobacco thrips, *Frankliniella fusca* (Hinds), on peanuts were conducted in Alabama from 1952 through 1956. Aldrin and dieldrin granules applied to the soil at 2 pounds per acre before planting were significantly more effective for thrips control on seedling peanuts than endrin, heptachlor, lindane, or toxaphene granules. The residual effectiveness of aldrin and dieldrin was greater on clay soil than on sandy soil. Thimet and Di-Syston dusts applied to the soil were significantly more effective than aldrin granules. Plants growing on Thimet- or Di-Syston-treated plots yielded more peanuts than untreated check plots, but the gains in yield were not significant.

The tobacco thrips, *Frankliniella fusca* (Hinds), damages seedling peanuts by rasping the epidermis of unopened leaflets causing scarred, deformed leaves. When thrips infestations are heavy, seedlings become stunted for several weeks.

Foliage applications of DDT, BHC, and toxaphene (Poos 1945, Poos *et al.* 1947, Arant 1954); soil applications of aldrin and dieldrin granules (Dogger 1956); and several organophosphate insecticides (Howe & Miller 1954, Arthur & Arant 1954, Dogger 1956) effectively controlled tobacco thrips on peanuts. However, increased yield of peanuts resulting from thrips control was not consistent.

Research was conducted in Alabama from 1952 through 1956 on control of tobacco thrips with chlorinated hydrocarbon and organophosphate insecticides applied to the soil, and on the relationship of thrips control to peanut yields.

Procedure.—The experimental design of field plots was essentially the same as that described by Arthur & Arant (1955). Treatments were replicated four times in randomized blocks that were separated by alleys 3 to 10 feet in width. Plots were 4 to 8 rows wide and 33.3 feet long.

Soil applications of insecticidal dusts and granules were applied broadcast by hand over the seedbed prior to planting or after emergence of the peanuts. In some experiments dusts and granules were applied to an open furrow in the seedbed at planting time. Emulsifiable concentrates were placed in the seedbed with a soil fumigant injector shortly before planting. The insecticides used, dosages, and time and interval of application are presented in tables 1, 2, 3, and 4.

Thrips infestation counts were made according to the procedure described by Arant (1954). Twenty bud tips about 2 inches in length were collected at random from the two outside rows of each plot and the number of thrips on the buds were counted. Yield of peanuts per acre based on 7% moisture content was determined by methods reported by Arthur & Arant (1954).

Results.—In 1952, two months after the application of aldrin, dieldrin, or heptachlor emulsifiable concentrates at 2 pounds per acre or dieldrin dust at 3 pounds per acre for soil insect control, it was observed that thrips damage was lighter and plants were larger on treated plots than on untreated. Plants growing on untreated plots were infested with an average of 100 thrips per 20 bud tips, whereas plants on aldrin-treated plots had an average of 65 thrips. Thrips populations on plants in other treated plots were about the same as those for the untreated check.

Table 1.—Number of tobacco thrips following application of granulated insecticides to the soil, 1954.

Treatment[a]	Dosage of Technical (Lb./A.)	Thrips[b] per 20 Bud Tips as Indicated by Dates and Location				
		Headland		Troy	Midland City	
		May 20	June 3	May 26	June 9	June 4
Untreated	—	124	286	89	88	31
Aldrin	2	14	200	19	33	9
DDT[c]	4	90	308	94	98	—
Dieldrin	2	25	229	11	32	1
Heptachlor	2	107	295	73	67	19
Lindane	2	96	308	82	84	28
Toxaphene	6	114	267	107	100	33
L.S.D. at 5% level		36	72	33	32	22
at 1% level		50	—	46	44	31

[a] Insecticides applied to the soil: Headland, April 28; Troy, April 19; Midland City, April 28, 1954. Peanuts planted approximately 2 days later.
[b] Number of thrips averaged from four replicates.
[c] Applied to the soil as a dust.

Observations in 1952 on control of thrips with insecticides applied to the soil were substantiated in 1954 (table 1). In general, plants on plots treated with aldrin or dieldrin granules had significantly fewer thrips than those on untreated checks or on plots treated with heptachlor, lindane, or toxaphene granules or with DDT dust. Aldrin or dieldrin granules were effective for thrips control for about 3 weeks on gray sandy loam soil at Headland; 5 weeks on reddish-brown sandy loam soil at Midland City; and 7 weeks on clay loam soil at Troy (table 1).

Results of experiments in 1955 on the effect of soil-applied insecticides on thrips populations are given in tables 2 and 3. Seven weeks after preplanting applications of aldrin granules or Thimet dust to the soil, thrips infestations on the plants were significantly lower than in check plots or plots treated with endrin granules. Thimet

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Table 2.—Number of thrips following application of insecticides to the soil, 1955.

Treatment[a]	Dosage of Technical (Lb./A.)	Thrips[b] per 20 Bud Tips on June 10
Untreated	—	134
Aldrin	2	49
Endrin	2	133
Thimet	2.5	9
Thimet	5	5
L.S.D. at 5% level		37
at 1% level		52

[a] Aldrin and endrin granules and Thimet dust applied to the soil immediately prior to planting at Headland on April 22, 1955.
[b] Number of thrips averaged from four replications.

Table 3.—Number of thrips following postemergence applications of insecticides to the soil, 1955.

Treatment[a]	Dosage of Technical (Lb./A.)	Thrips[b] per 20 Bud Tips as Indicated by Dates	
		June 11	June 24
Untreated	—	127	82
Dieldrin	2	18	24
Toxaphene	6	135	87
Thimet	4	108	92
L.S.D. at 5% level		28	28
at 1% level		41	40

[a] Dieldrin and toxaphene granules and Thimet dust applied broadcast to the soil at Headland prior to cultivation of peanuts on May 9, 1955.
[b] Number of thrips averaged from four replications.

dust was significantly more effective than aldrin granules for thrips control (table 2). Dieldrin granules applied as a postemergence sidedress treatment were highly effective in reducing thrips populations, whereas toxaphene granules or Thimet dust was not effective (table 3).

In 1956, Thimet and Di-Syston® (formerly called Bayer 19639) soil treatments were compared with postemergence applications of aldrin and heptachlor granules for thrips control (table 4). On June 7, all treatments except heptachlor resulted in highly significant control of thrips when compared with untreated plants. Thimet at 1, 2.5, or 5 pounds of technical material per acre or Di-Syston at 5 pounds were significantly more effective than aldrin granules at 2 pounds per acre; aldrin was significantly more effective than heptachlor. Eleven days later, on June 18, thrips populations had increased considerably on treated and untreated plots. Aldrin granules were no longer significantly effective, but Thimet and Di-Syston were still highly effective for control of thrips.

Though not significant, sizable yield gains over the checks were obtained with Thimet and Di-Syston treatments in 1956 (table 4). Plots treated with heptachlor and aldrin granules yielded about the same as untreated check plots.

Table 4.—Number of thrips and yield of peanuts following application of insecticides to the soil, 1956.

Treatment[a]	Dosage of Technical (Lb./A.)	Thrips per 20 Bud Tips as Indicated by Dates[b]		Yield (Lb./A.)
		June 7	June 18	
Untreated	—	28	74	1,584
Thimet	1	5	32	1,853
Thimet	2.5	3	13	1,772
Thimet	5	1	15	2,019
Di-Syston	2.5	9	30	1,834
Di-Syston	5	3	18	1,793
Aldrin	2	13	51	1,561
Heptachlor	2	25	55	1,600
L.S.D. at 5% level		7	31	none
at 1% level		10	41	none

[a] Thimet and Di-Syston dusts on activated charcoal applied to open furrows immediately before planting at Headland on April 18, 1956; heptachlor and aldrin granules applied over surface of rows on May 9 after emergence.
[b] Number of thrips averaged from four replications.

References Cited

Arant, F. S. 1954. Control of thrips and leafhopper on peanuts. Jour. Econ. Ent. **47**(2): 257–63.

Arthur, B. W., and F. S. Arant. 1954. Effect of systemic insecticides upon certain peanut insects and upon peanuts. Jour. Econ. Ent. **47**(6): 1111–4.

Arthur, B. W., and F. S. Arant. 1956. Control of soil insects attacking peanuts. Jour. Econ. Ent. **49**(1): 68–71.

Dogger, J. R. 1956. Thrips control on peanuts with granulated insecticides. Jour. Econ. Ent. **49**(5): 632–5.

Howe, W. L., and L. I. Miller. 1954. Effect of demeton soil drenches on peanut pests. Jour. Econ. Ent. **45**(4): 711–2.

Poos, F. W. 1945. The control of tobacco thrips on seedling peanuts. Jour. Econ. Ent. **38**(4): 446–8.

Poos, F. W., J. M. Grayson, and E. T. Batten. 1947. Insecticides to control tobacco thrips and potato leafhopper on peanuts. Jour. Econ. Ent. **40**(6): 900–5.

Beetles Found in Yellow Pine Floor Joists of Buildings in North Carolina[1]

C. G. Wright,[2] *North Carolina State College, Raleigh*

An increasing number of inquiries are being received in North Carolina by entomologists and pest control operators for control recommendations for a group of insects, simply identified as powder-post beetles, which occur in yellow pine joists and subflooring. There is no record of specific identification of these beetles, therefore a survey was undertaken to determine the species involved.

Pest control operators throughout the state were asked to supply samples of wooden floor joists containing powder-post beetle infestations. The location where the sample was collected, the name of the owner of the building, and the date collected were also requested. The infested samples were put in 1-gallon jars with covered tops and placed in a constant temperature room. Periodical checks were made and any beetles that had emerged from the wood were mounted, labeled and sent to the United States National Museum for identification.[3]

Three species were collected from the wood sections. *Xyletinus peltatus* Harris (Coleoptera, Anobiidae), reared from 10 different wood samples, was collected throughout the state. Records in Leng (1920) and Brimley (1938) confirm this statement. The host is not given in these references.

Hadrobregmus carinatus (Say) (Coleoptera, Anobiidae) was found in one wood sample from north eastern North Carolina. Earlier, Leng (1920), reported this beetle from the "Black Mountain of North Carolina." These are the only records of this species in the state.

Hexarthrum ulkei Horn (Coleoptera, Curculionidae), reported for the first time in North Carolina, emerged from three different wood samples collected in the north central part of the state.

References Cited

Brimley, C. S. 1938. The insects of North Carolina. 560 pp. N. C. Dept. Agric., Raleigh.

Leng, Charles W. 1920. Catalogue of the Coleoptera of America North of Mexico; 470 pp. John D. Sherman, Jr., Mt. Vernon, New York.

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[2] Now with the Wilson Exterminating Company, Winston-Salem, N. C.
[3] Thanks are given to Jerome G. Rozen, T. J. Spilman and Rose Ella Warner of the Entomology Research Division, U. S. Department of Agriculture, for identifications of specimens

Longevity of Overwintered and First Generation Boll Weevils at Florence, S. C.[1]

R. E. Fye,[2] W. W. McMillian,[3] A. R. Hopkins,[2] and R. L. Walker[2]

Abstract

The average life of overwintered boll weevils (*Anthonomus grandis* Boh.) after emergence from hibernation was found to be 20 to 22 days, and ranged from 1 to 141 days. Fat analyses showed that weevils containing most crude lipids lived the longest. First-generation weevils lived 9 to 115 days, with an average of 41.5 days. There was no correlation of total crude lipids with longevity in the first generation.

One of the factors determining the value of an early-season control program for the boll weevil (*Anthonomous grandis* Boh.) is the life span of the overwintered weevils after they leave hibernation quarters. Only if the span is fairly long will the control of these survivors be practicable.

Early work of Hunter & Hinds (1905) in Texas indicated that the winter survivors had an average spring life of 80 days for males and 70 for females. These weevils were held in the laboratory under seemingly ideal conditions. They further found the average life span of first-generation weevils to be 58 days for males and 56 days for females.

Fenton & Dunnam (1929) studied the longevity of overwintered boll weevils after emergence from hibernation at Florence, S. C. They found that weevils placed on nonsquaring seedling cotton lived an average of 8.1 days in field cages and 14.0 days in glass tumblers in the insectary; the maximum was 40 days in both studies. On squaring cotton in field cages males lived an average of 19.4 and females 16.1 days; the respective maxima were 69 days for males and 48 for females. In longevity studies on first-generation weevils, males lived an average of 18.3 days with a maximum of 67 days and females averaged 14.5 days with a maximum of 74 days.

Field-cage studies to determine the longevity of overwintering boll weevils after emergence from hibernation were again conducted at Florence in 1956 and 1957. These studies were similar to the earlier work of Fenton and Dunnam, but the cage technique was modified. In addition the relationship between the fat content and longevity was investigated. Similar studies were conducted on the longevity of first-generation weevils.

Methods.—Weevils taken from standard hibernation cages after May 1 were transferred to cylindrical screen cages that had been placed over seedling cotton. Light-colored builder's sand was used to cover the soil surface around the seedlings, so that the dead weevils were readily detected. No more than 10 weevils were placed in any cage, and as the young seedlings were destroyed the cages were moved to an undamaged group of seedlings. As the cotton grew, the surviving weevils were transferred to larger cages over the older plants so that they were maintained on plants of normal field age. Each day the dead weevils were counted, sexed, and preserved for fat analysis. At the end of the season, standard fat extractions of the dead weevils of various ages were made with ethyl ether to determine possible relationship between their fat content and longevity. First-generation weevils, which emerged on July 11, were handled in a similar manner but were introduced directly onto cotton of field age.

Results.—These studies (table 1) indicate a somewhat longer life span for boll weevils after emergence in the spring than was found by Fenton and Dunnam. This discrepancy might be due to differences in weather conditions. Since both studies covered only a few years, the true average longevity based on many years' observations may differ somewhat from that found. However, some selection of weevils better adapted to South Carolina conditions could have occurred since Fenton and Dunnam's studies, for they obtained their data shortly after South Carolina was invaded by the boll weevil.

A difference is also reflected in the maximum ages reached by the weevils. Fenton and Dunnam's 69-day maximum is fairly well in line with the 53-day maximum attained in 1956. However, compared with the life spans reached in 1957, both the 1956 and 1924–26 figures appear to be low.

It appears that a complex of factors, mainly climatic, determine the longevity of overwintered weevils after their emergence in the spring. This conclusion confirms the earlier work of Hunter and Hinds (1905) which

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[2] Entomology Research Division, Agric. Res. Serv., U.S.D.A.
[3] South Carolina Agricultural Experiment Station.

Table 1.—Longevity of boll weevils after emergence from hibernation and of the first generation, 1924–26, 1956–57.

Year and Sex of Weevils	Number of Weevils	Longevity (Days)	
		Average	Range
	Overwintered		
1956			
Male	128	20.6	1– 53
Female	70	19.5	2– 44
Total or average	198	20.2	
1957			
Male	66	23.9	1–141
Female	59	23.4	4– 93
Total or average	125	23.6	
1924–26[a]			
Male	115	19.4	2– 69
Female	110	16.1	2– 48
Total or average	225	17.8	
	First Generation		
1957			
Male	9	33.0	9–115
Female	23	44.8	19–115
Total or average	32	41.5	
1924–26[a]			
Male	88	18.3	1– 67
Female	106	14.5	1– 74
Total or average	194	16.2	

[a] Fenton & Dunnam (1929).

Table 2.—Per cent of boll weevils living at indicated days after emergence, 1956–57.

Days	1956 Overwintered			1957 Overwintered			1957 First Generation		
	Male	Female	Average	Male	Female	Average	Male	Female	Average
10	64.1	60.0	62.7	57.6	69.5	63.2	88.9	100.0	96.9
20	46.9	45.7	46.5	34.9	49.1	41.6	44.4	95.7	81.2
30	36.7	31.4	34.9	28.8	32.2	30.4	22.3	73.9	59.4
40	9.4	5.7	8.1	15.2	11.8	13.6	22.3	65.2	53.1
50	0.8	0	0.5	12.2	6.7	9.6	22.3	8.7	12.5
60	0	—	0	7.7	3.3	5.6	22.3	8.7	12.5
70	—	—	—	6.2	3.3	4.8	11.2	8.7	9.4
80	—	—	—	4.7	1.6	3.2	11.2	8.7	9.4
90	—	—	—	3.2	1.6	2.4	11.2	8.7	9.4
100	—	—	—	3.2	0	1.6	11.2	8.7	9.4
110	—	—	—	3.2	—	1.6	11.2	8.7	9.4
120	—	—	—	3.2	—	1.6	0	0	0
130	—	—	—	3.2	—	1.6			
140	—	—	—	1.6	—	0.8			
150	—	—	—	0	—	0			

showed the average life span after spring emergence to be 70 to 80 days under seemingly ideal laboratory conditions.

Table 2 indicates that approximately 30% of the overwintered weevils live 30 days after emergence and about 10% live 40 days. If this is the situation in field populations, then a fair percentage of these weevils are present when the cotton begins to square about the first week in June. Since the crop produced by these early squares is essential to maximum production, a control program should be aimed at these overwintering weevils.

The longevity data for first-generation weevils show the 1956–57 averages and maxima (table 1) to be higher than the 1924–46 averages of Fenton & Dunnam (1929). Again ecological adaptation and selection could have occurred over the intervening period, but the 15 to 30-day differences seem to be an exaggeration of this phenomenon. This view is supported by the work of Hunter & Hinds (1905), who found that first-generation males lived an average of 58 days and females 56 days. Those averages were higher than the 1956–57 Florence averages, but the fact that they were obtained under laboratory conditions would probably account for the differences. It is apparent from these data that weevils of the first generation have a rather long life and would be troublesome throughout the cotton-production season.

Table 3.—Per cent of crude lipids in the overwintered and first-generation boll weevils, 1956–57.

Days	1956 Overwintered		1957 Overwintered		1957 First Generation	
	No. of Weevils	Per Cent Fat	No. of Weevils	Per Cent Fat	No. of Weevils	Per Cent Fat
1– 10	71	7.6	45	5.9	1	15.8
11– 20	30	9.9	26	6.4	4	19.7
21– 30	27	14.9	14	9.9	7	19.1
31– 40	48	16.1	16	6.8	2	26.2
41– 50	14	20.9	5	16.9	13	8.9
51– 60	1	33.7	5	12.4	—	—
61– 70	—	—	1	23.6	—	—
71– 80	—	—	1	17.9	—	—
81– 90	—	—	1	32.2	—	—
91–100	—	—	1	24.1	—	—
111–120	—	—	—	—	3	15.2
131–140	—	—	2	28.4		

The fat-analysis data for the various age groups (table 3) show a general trend for overwintered weevils with higher lipid content to live longer. It is further apparent that the lipids are not utilized to a specific level at which point death ensues. Thus, if fat is involved in the longevity picture, it appears to be qualitative rather than quantitative.

First-generation weevils did not show the tendency to live longer when their fat content was higher. They also appeared to have a more constant percentage of fat. This constancy was to be expected, since the first-generation weevils had similar larval and adult diets whereas the overwintered weevils probably had a more varied diet before their entrance into hibernation.

References Cited

Fenton, F. A., and E. W. Dunnam. 1929. Biology of the cotton boll weevil at Florence, S. C. U. S. Dept. Agric. Tech. Bull. **112,** p. 33–5.

Hunter, W. D., and W. E. Hinds. 1905. The Mexican cotton boll weevil. U. S. Dept. Agric. Bur. Ent. Bull. **51,** p. 44–8, 53–4.

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Food Habits of *Solenopsis saevissima richteri* Forel[1]

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ABSTRACT

Experiments were conducted in 1957 to determine food habits of the imported fire ant, *Solenopsis saevissima richteri* Forel, by field observations and laboratory experiments. Ant mounds were dissected in the field to determine food storage, and ants were observed at work to determine the food materials collected by the foraging ant parties. This investigation revealed that the ant is somewhat omnivorous; however, the primary dietary item was insects, both alive and dead. The ant was also observed to tend aphids and scale insects. In only one instance was it observed feeding on vegetative matter; but in the laboratory, when kept without food for several days, it fed on a few species of seedling plants. Most colonies became cannibalistic rather than feed on plant material. On occasion they were observed to carry seeds to the nest.

The imported fire ant, *Solenopsis saevissima richteri* Forel, has been reported to damage or destroy many major agricultural crops, to kill young livestock, and to be a major factor in the decline of some pasture areas in the Southeastern States. As a pest of wildlife, it has reportedly entered pipped quail eggs and devoured the young.

Yates & Smith (1935) reported imported fire ant damage to seedling corn at the Gulf Coast Substation of the Agricultural Experiment Station, Alabama Polytechnic Institute. Travis (1938) made the first report of damage to wildlife by ants belonging to the genus *Solenopsis*. Bruce *et al.* (1949) reported that the ant was omnivorous. They found the ants feeding on honey dew obtained from aphids and on scale insects and mealybugs. They noted that the ants would gather seeds from wild and cultivated plants; feed on the germinating portion of planted seed corn; gnaw holes in the stalks, pods and buds, and girdle many plants. Damage to corn, peanuts, beans, Irish potatoes, okra, cabbage, collards, watermelons, squash, soybeans, sweetpotatoes, tomatoes, strawberries, cantaloupe, and other field crops was also reported. They reported that the ants would feed on their own species and other insects, were attracted to blood and other moist matter of newly hatched birds, and would enter houses in search of meats and other proteinaceous foods.

In a special report to the Alabama Department of Conservation, Wilson & Eads (1949) indicated that the imported fire ant was a major crop pest in the state. They concluded that the ants were damaging pine seedlings, seeds of corn, peanuts and beans, and roots, stems, and leaves of corn, beans, Irish potatoes, collards, watermelons, and squash. They also reported that the ant damaged bee colonies.

Lewis (1950) reported the primary dietary item of the imported fire ant was insects. Solomon *et al.* (1957) found no fire ant damage to vegetation in Argentina. They reported that the ant fed upon various insects, many of which were economic species. Lyle & Fortune (1948) in the first report dealing with food habits of the ant, stated that the ants ate meat and bread, but showed no interest in sweets. They also reported that germinating seed was eaten. Theirs was the first paper reporting that farm livestock was killed at birth by the ants.

In 1957 a study was begun to determine the food habits of the imported fire ant in Alabama.

PROCEDURE.—The experiments and observations reported herein were conducted at the Main Experiment Station, Black Belt Substation, and Lower Coastal Plain Substation of the Agricultural Experiment Station of the Alabama Polytechnic Institute.

A total of 95 mounds was dissected to determine mound structure, the kinds and amounts of stored food, and the methods of storage. Prior to dissecting the mound, the ants were killed by pouring 20 to 30 ml. of chloroform over the mound. The dissected mounds were picked at random in areas representing three major soil types—Lower Coastal Plains sand at Auburn and Camden, Black Belt clay at Marion Junction, and Piedmont clay at Auburn. A small trench was dug around each of 15 other mounds and observations were made of ants returning from the surrounding area to determine what food was being transported to the mound. The observations were made from March through November. Each of these mounds was observed for an average of approximately 3 hours. When the next observation was made, a new mound was selected. In addition to these observations, living insects in small wire cages were placed on ant mounds in the field and dead insects were placed in the area surrounding the mounds to see if they would be utilized as food by the ants.

Small ant colonies were established in the laboratory to study their food habits more completely. A series of tests, using the seed and plants of crops the ant had been reported to damage, were begun in order to evaluate the magnitude of damage.

Each colony was placed in a glass battery jar that was surrounded by water to keep the ants in the jar, and left for 2 to 3 days without food. Dry seeds of the following plants were placed on the mound and left for 2 to 3 days: cucumber, okra, tomato, squash, watermelon, oat, crimson clover, corn, soybean, Irish potato, dahlia, pansy, zinnia, petunia, peanuts, lima bean, and cotton. Only one type of seed was placed on a mound at one time. Each test was replicated four times. Experiments were also conducted to determine the amount of damage to seedling plants. Plants were transplanted from greenhouse flats into the mounds and also grown from seed in the mounds. Plants and seed of cucumber, squash, watermelon, okra, English pea, bean, soybean, peanut, corn, Irish potato, cabbage, tomato, cantaloupe, pine, pansy, marigold, and cotton were used. One plant was used per mound with treatments replicated four times. The plants remained in the mound for a period of 6 weeks. During the period, the mounds were watered to supply moisture to the plants, but no source of food other than the plant was available to the ants. Colonies of ants in the laboratory were offered living insects of various species to see what species they would attack and how they killed their prey. Only one species of insect was offered to a colony at

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a time, and each species was placed on four colonies of ants. The insects were confined to the ant colony by the use of a lamp globe having the top covered with a nylon stocking. Whole and crushed dead insects were offered the ants. The latter insects were obtained from an insect light trap and represented many families. Apple branches containing apple aphids were brought into the laboratory and placed on a colony in such a way as to preserve the branches for several days.

Ants were observed at cold temperatures to determine the effect of temperature on ant activity. A small, vigorous colony of ants was placed in a cooler and observations were made as the temperature was decreased. The temperature was decreased gradually over a 3-day period to a final temperature of 4 degrees C. The ants remained at this reduced temperature for an additional period of 3 days.

RESULTS.—Depth of mounds varied in proportion to the mound size above the ground surface. The underground portion of the mound was usually a mirror image of the aboveground parts, except for a few of the underground tunnels that extended to depths greater than 4 feet.

Of the 95 mounds dissected 72 mounds contained no food material of any kind, 13 contained stored food, and in 10 mounds there was evidence that food had been stored. The stored food was located in blind, enlarged tunnels or cells in the underground portion of the mound. Cells of some of the mounds located near woodland areas contained living and dead termites. One mound near a clover-grass pasture in Lee County had five storage cells filled with weevils, primarily *Hypera meles* (L.) and *H. nigirostris* (L.). They were found in clusters of 5 to 10 per cell. Most of the insects had been eviscerated by the ants; however, some specimens were still intact. Parts of other coleopterous insects were also found in storage.

Several unharmed cutworms were taken from some of the mounds. These cutworms were always located in the soil of the mound and not in the tunnels and had probably migrated into the nest without being discovered by the ants. On several occasions large pupal cases were discovered in tunnels of the mounds. They showed evidences of having been eviscerated by the ants. Since they were too large to have been transported to the mound, the larvae probably had migrated into the mound and pupated before being discovered by the ants. Snail shells were found in and around the mounds; however, there was no way to determine if they had been killed and eaten by the ants. In one mound a number of adults were found feeding on a large fire ant pupa. Cannibalism had been noted previously in the laboratory, but this was the only instance of cannibalism of immature forms observed in the field.

At all openings along tunnels that radiate from the mound, workers were observed coming from and going into the tunnels. At these openings insects that were eviscerated and various parts of insects that had been excised by the ants were found. Observations at one opening revealed that the ants brought aphids, small spiders, larvae of different species, and some beetles to the opening and devoured them. Fly larvae seemed to be a favorite food. In one mound located near shade where cow dung was plentiful and fly larvae were easy to obtain, the ants visited each pile of dung, collected the larvae, and took them into the tunnel. Live insects placed in wire cages near the mounds were immediately attacked and killed by the ants. The soft portions of the insects were carried into the mound. Dead insects placed in the area were carried to tunnel entrances and devoured. In the areas around the mounds, ants were found foraging in all directions. Where food had been found and the ants had fed, they entered the tunnel and returned to the mound. Observations revealed that the ants occasionally returned to the mound with a visible food particle. On one occasion the ants were observed carrying seeds along a trail in a wooded area.

Ants were encountered attacking immature and mature forms of centipedes and millipedes. Living arthropods served only as a part of their natural food. Dead arthropods and fragments of arthropods were found by foraging workers and utilized as food.

Imported fire ants were observed in the field tending aphids and scale insects on several species of plants. Apple aphids on branches placed on colonies in the laboratory were also tended by the ants. The principle dietary item, as noted in the field, was not vegetation but other insects, both living and dead. There seemed to be no preference between these two, since the ants took the dead as quickly as the living insects when both were available. Larval forms were preferred over the adults, especially those that were small enough to be easily transported.

Where ears of corn touched the ground, mounds were constructed around the ear, and the grains of corn were consumed by the ant. The ants were not observed to climb the stalk to feed on corn grains. Although some corn was damaged, far more important was the sting of the ants that interferred with hand-harvest operations. No other injury to vegetation was noted in the natural habitat of the imported fire ant.

Imported fire ant colonies were observed to move for no apparent reason. The queen and brood were transported along the trail of ants into a newly prepared mound. No visible food was observed in this movement. If food was present in the old mound, none was moved.

Results of laboratory studies revealed that of 17 kinds of dry seeds placed on the mounds only peanuts were eaten. The ants did not damage or move seeds of the other plants. When germinating seed of these plants were made available to the ants, they ate only peanuts, okra, and corn. A thorough examination of roots and aboveground parts of 18 species of seedling plants transplanted into mounds and allowed to grow for 6 weeks revealed no damage by the ants. The 18 species of plants produced from seed in the mound grew with no damage to the seed and damage to okra plants only. The ants seriously damaged 10% of the young okra plants and killed 5%; the damage to the other 85% was not sufficient to reduce their growth.

In most of the colonies receiving no food except growing plants, the ants became cannibalistic instead of eating the plants. Examination of ant fragments brought from the mounds indicated that the ants had been eaten by other members of the colony. It was not ascertained whether these ants were killed or had died from other causes.

When living insects were placed on the mound in the laboratory, the ants immediately covered the insects and stung them until they could no longer move. After the insects were immobilized, the ants cut them into

pieces and devoured all but the integument. One small young colony took 15 armyworm larvae at one feeding. House fly larvae were taken into the mound, whereas armyworm larvae were cut into pieces, eaten, or carried into the mound.

The following is a list of the living insects offered the imported fire ant in the laboratory.

Adults

A grasshopper—*Melanoplus* sp.
Three-cornered alfalfa hopper—*Spissistilus festinus* (Say)
American cockroach—*Periplaneta americana* (L.)
American grasshopper—*Schistocera americana* (Drury)
Ash grey lady beetle—*Olla abdominalis* (Say)
Boll weevil—*Anthonomus grandis* Boh.
Brown stink bug—*Euschistus servus* (Say)
Common lady beetle—*Coccinella sanguinea* L.
Confused flour beetle—*Tribolium confusum* Duv.
Fruit fly—*Drosophila melanogaster* Meigen
German cockroach—*Blattella germanica* (L.)
Harlequin bug—*Murgantia histrionica* (Hahn)
Longhorn grasshopper—Tettigoniidae
Lesser clover leaf weevil—*Hypera nigrirostris* (F.)
Mexican bean beetle—*Epilachna varivestis* Muls.
Oriental cockroach—*Blatta orientalis* L.
Southern pine sawyer—*Monochamus titillator* (F.)
Nine-spotted lady beetle—*Coccinella novempunctata* (Herbst.)
Two-spotted lady beetle—*Adalia bipunctata* (L).

Larvae

Armyworm—*Pseudaletia unipuncta* (Haw.)
Cabbage looper—*Trichoplusia ni* (Hbn.)
Cutworm—Phalaenidae
Fall armyworm—*Laphygma frugiperda* (J. E. Smith)
Green cloverworm—*Plathypena scabra* (F.)
House fly—*Musca domestica* L.
Squash vine borer—*Melittia cucurbitae* (Harr.)
Soldier beetle—*Chauliognathus pennsylvanicus* Deg.
Spotted cucumber beetle—*Diabrotica undecimpunctata howardi* (B.)
Yellow-striped armyworm—*Prodenia ornithogalli* Guen.

Of the insects listed above, only the American grasshopper was not eaten by the ants. It hopped around and escaped.

Of the whole, dead insects offered the ants, the larger insects seemed to be preferred. The ants cut into the insects, devoured the viscera, and left the exoskeletons on the mound. Some of the smaller insects were carried underground in one piece where apparently they were consumed, since at a later date, they were not found in storage. All species of insects were accepted without exception.

Insects, dead or alive, whole or crushed, were more attractive to the ants than any other food source. Insects were accepted when all other items were refused as food.

An examination of the colony in cold storage at 4 degrees C. revealed that the ants were located in the center of the nest and, that individuals were completely immobilized by the temperature. As the temperature declined they retired to the center of the nest and formed an aggregate around the queen. The ants resumed normal activities after warming to room temperature. No larvae or pupae were included in this investigation.

References Cited

Bruce, W. G., J. M. Coarsey, Jr., M. R. Smith, and G. H. Culpepper. 1949. Survey of the imported fire ant, *Solenopsis saevissima* var *richteri* Forel. U.S.D.A. Bur. Ent. and Pl. Quar. Special Rept. **S-15.** 25 pp.

Lewis, L. F. 1950. Investigations in the biology of the imported fire ant. (Unpublished Rept., U.S.D.A., Bur. Ent. and Pl. Quar., Savannah, Ga.)

Lyle, Clay, and Irma Fortune. 1948. Notes on an imported fire ant. Jour. Econ. Ent. **41**(5): 833–4.

Solomon, E. R., S. C. Dyar, and K. L. Hays. 1957. Report of committee appointed by the Governor on study of methods of control of the Argentine fire ant. Legislative Document No. 4. State of Alabama. 7 pp.

Travis, B. V. 1938. The fire ant (*Solenopsis* spp.) as a pest of quail. Jour. Econ. Ent. **31**(6): 649–52.

Wilson, E. O., and J. H. Eads. 1949. A report on the imported fire ant, *Solenopsis saevissima* var *richteri* Forel, in Alabama. (Special rep. to Ala. Dept. of Conservation.) 71 pp.

Yates, Harold, and M. R. Smith. 1935. First report of crop damage by the imported fire ant. (Rep. from API Gulf Coast Sub. Sta. Assistant Superintendent and U.S.D.A. representative.)

Protection of Stored Woolens from Insect Damage[1]

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Abstract

Various control techniques were evaluated as methods of protecting stored woolens. The use of tightly sealed plastic containers as barriers prevented larvae of the black carpet beetle (*Attagenus piceus* (Oliv.)) and larvae of the webbing clothes moth (*Tineola bisselliella* (Hum.)) from attacking stored woolens. Formalin and paradichlorobenzene (PDB) fumigants were effective against clothes moth adults, but both were ineffective against the carpet beetle larvae. The residual spray technique, employing 5% DDT, 5% methoxychlor, 1.25% lindane, 2% chlordane, 0.5% dieldrin, or 0.5% Diazinon, did not give satisfactory kill of the carpet beetle larvae. The hazards involved in using DDT, chlordane and other impregnants were considered. For the homemaker, the barrier technique using tightly sealed plastic containers is recommended as an easy and effective control measure.

During the summer months most woolens are either placed in garment bags and hung in closets or put into trunks which are kept in attics, basements, or other out-of-the-way places. These stored woolens are subject to damage from two kinds of insects, namely clothes moths (especially *Tineola bisselliella*) and carpet beetles (especially *Attagenus piceus*). The problem of protecting stored woolens from these destructive pests was investigated and the results are reported herein.

Control Techniques.—Populations of economically important fabric pests are controlled by various tech-

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niques. Of these the use of barriers, fumigation, residual treatments, and fabric impregnation were considered most applicable to the control of insect pests. These techniques, therefore, formed a basis for the studies described in this paper.

Barriers.—Placing thoroughly clean woolens behind an obstacle which prevents clothes moths and carpet beetles from reaching the fabric has long been a simple and effective control measure. Tightly sealed trunks and closets fall in this category. At present the new plastic bags and similar containers with nearly airtight closings are effective in barring the entrance of these insects. We have found in experiments that neither carpet beetles nor clothes moth larvae are able to chew through a thin (1.25 mil.) film of polyethylene plastic or heavy (70-lb. kraft 36-inch) wrapping paper to reach wool cloth. Clothes moth larvae have been observed to work their way through light (No. 1 filter paper) loose-fibred paper. If the woolens are insect-free and placed into some clean insect-proof container (plastic container preferable) they will suffer no damage from either moths or beetles.

Fumigation.—Homemakers commonly use PDB in storage containers to protect woolen clothes. This material is effective in killing clothes moths when used liberally, but there is a question concerning its effectiveness against carpet beetles (Molnar 1947, Arnold 1953). Formalin, a good fungicide (Furry *et al.* 1941), was reported to be a reliable insecticidal fumigant (Harvey & Hill 1947), but evidence indicated it was inadequate as an insecticidal spray (Scott *et al.* 1918). Therefore, questions which seemed unanswered were: 1) Is PDB equally effective against clothes moths and carpet beetles? 2) Is formalin, an effective fumigant against clothes moths and carpet beetles?

The two species of insects employed in the first experiments were the webbing clothes moth and the black carpet beetle. Only adults of the clothes moth were used in the tests with fumigants because it is the adult of this species that usually gains entrance to stored woolens. The senses of the adult are more responsive to food stimuli than are those of the larvae and thus the adults more easily locate a source of larval food than the larvae; also the adults have greater vagility than the larvae, allowing them to search a greater area for larval food than the larvae (Nachman 1958). Both the larvae and adults of the clothes moth are negatively phototropic seeking dark areas such as closets, trunks, etc. With the carpet beetle, however, it is the larvae that usually gain entrance to stored woolens. These vagile larvae are probably easily attracted to certain larval foods as are other dermestids (Imamura 1935). The carpet beetle larvae are also strongly negatively phototropic and this characteristic aids them in locating stored woolens. The adult carpet beetles are positively phototropic which may account for the fact that they are not as effective in finding stored woolens as the larvae. Thus the larvae were used in all the tests, however, adults were also used in this particular test.

Treatments using formalin and PDB were compared with a control. One square foot of new wool cloth was dusted with about 1 gram of brewer's yeast and placed into each wide-mouth gallon jar used to simulate a storage container. The test chemicals were placed in a shell vial ($\frac{5}{8}$-inch diameter by $2\frac{1}{2}$ inches). Each vial was three fourths filled and placed in an upright position in a gallon jar. No chemicals were placed in the vials in the control containers. Both liquid formalin (40%), and PDB crystals were added to each of 10 jars. Five jars for each of the two treatments were used to expose clothes moths and the other five to expose black carpet beetles. Three untreated jars served as control for the clothes moth tests and five untreated jars were used as controls for the tests with the black carpet beetle. A metal cover was placed in an inverted position over the mouth of each jar to make it insect tight, but not completely airtight.

Table 1.—The effectiveness of formalin and PDB against clothes moths.[a]

Treatment	Total No. of Moths Introduced	Number of Moths Alive	Total No. Present		Damage Observed
			Larvae	Pupae	
Untreated	123	13	15	7	Severe
Formalin	152	0	0	0	None
PDB	141	0	0	0	None

[a] Three introductions of moths were made during the one month test period; the last introduction was made about 7 days before the final examination.

All jars were allowed to stand for 3 days before the moths or beetles were introduced. When using clothes moths, from 8 to 15 adults were introduced three times, at weekly intervals, into each of 13 test jars. At the end of 4 weeks the dead and living life stages of the clothes moths were counted and the damage to the woolen cloth evaluated. With the carpet beetles, 10 adults and 10 fifth instar larvae were introduced into each of the 15 test jars only at the beginning of the test. Following 2 weeks' exposure, mortality counts were made, and damage to the test woolens was evaluated.

The results, tabulated in tables 1 and 2 indicate that both formalin and PDB were equally effective in preventing clothes moths from damaging woolen cloth under the test conditions, but were ineffective in preventing carpet beetle damage. The results with PDB against carpet beetle larvae agree favorably with those of Molnar (1947) who also found it ineffective. Even though PDB did not destroy the larvae, it had a repellent effect which reduced the amount of damage. This repellent effect and reduced damage has been reported by other workers (Molnar 1947, Moncrieff 1950, Arnold 1957).

In another test, five trunks were treated with formalin (40%). The trunks varied as to construction but were approximately of the same capacity, 14,000 cubic inches (about 3 feet by 1.5 feet by 1.5 feet). A small amount of formalin was poured over the sides and bottom of each trunk, in order to dampen the surface and bring the formalin vapor up to saturation quickly. Clean clothes,

Table 2.—The effectiveness of formalin and PDB against carpet beetle adults and larvae.

Treatment	No. Introduced		Number Alive After 2 Weeks Exposure			Damage Observed
	Adults	Larvae	Adults	Pupae	Larvae	
Untreated	50	50	44	5	45	Severe
Formalin	50	50	8	2	45	Moderate
PDB	50	50	4	1	42	Moderate

both woolen and cotton, were placed in the trunks to fill them. Then a wide-mouth pint Mason jar filled one fourth full of 40% formalin was placed into each trunk. The cracks around the lid were covered with masking tape. For the test period of 3 months the temperature inside the trunks averaged 80° F. (±10°); the relative humidity averaged 65% and ranged between 50 and 90%. The last week of test period, 200 to 400 adults of the confused flour beetle (*Tribolium confusum* Duv.) in a glass container with sufficient food, were introduced into each trunk to test the effectiveness of formalin under these conditions. *T. confusum* instead of clothes moths were used in this particular experiment because the woolen fabrics were loaned to the experimenters who were not at liberty to risk damage to the woolens. As a check, a container holding an equal number of adult beetles with food was maintained in the same room where the experiments were conducted and no mortality occurred during the experiment. In the treated trunks 100% of the beetles were dead at the end of 1 week. Thus, since clothes moth adults are relatively susceptible to formalin as indicated by the previous tests, it may be assumed that the formalin in the trunks would have been as effective against the susceptible moths as it was against the beetles.

In summary, PDB and formalin were both effective against the clothes moth, but were ineffective against carpet beetle larvae. Where mildew is a problem in addition to moths, formalin would have decided advantages since it is an effective control agent for mildew (*Chaetonium globosum*). PDB is not effective against mildew (Klotz 1936, Bateman & Baechler 1937).

Residual Surface Treatments.—The United States Department of Agriculture Home and Garden Bulletin No. 24 entitled, "Clothes Moths and Carpet Beetles—How to Combat Them," recommends 2% chlordane or 0.5% lindane or dieldrin as effective against carpet beetles if used as a surface spray (Anon. 1955a). Because of the scarcity of reported scientific experiments dealing with the effectiveness of these insecticides against carpet beetles, the following laboratory tests were designed to evaluate these and other organic insecticides, cleared for use in homes, for their lethal action against the black carpet beetle.

Treatments using DDT (5%), methoxychlor (5%), chlordane (2%), lindane (1.25%), dieldrin (0.5%), and Diazinon (0.5%) were compared with one another and a control. These commercial insecticides used were in an oil base. Concentration series were obtained by dilution with benzene. One milliliter of an insecticide solution was pipetted onto a filter paper (#595 S&S) 9 centimeters in diameter. The control was treated with benzene alone. The papers were thoroughly dried on the screen ($\frac{1}{8}$ mesh) rack for 24 hours, and then placed into petri dishes in preparation for the introduction of the test insects.

Each treatment was replicated a minimum of 10 times. For each replicate 10 fifth instar carpet beetle larvae were exposed to the treated filter paper for 45 minutes. The 45-minute exposure was selected because this was believed to be a reasonable time to expect the larvae to remain in contact with the residual surface treatments in houses in trunks and closets. This may have been too long an exposure when it is considered that carpet beetle larvae are known to travel an average speed of 12 inches per minute or a maximum speed of 22 inches per minute. If these insects were crossing over a treated baseboard, molding, or closet wall or trunk surface, at the speeds indicated, they could not be expected to obtain a lethal dose of any of the insecticides at the concentrations used in these tests.

Table 3.—Percentage mortality of carpet beetle larvae at various times following a 45-minute exposure to insecticidal residual deposits of various ages.

Days After Exposure	DDT (5%)	Methoxychlor (5%)	Lindane (1.25%)	Chlordane (2%)	Dieldrin (0.5%)	Diazinon (0.5%)	Untreated Check
1	1	0	1	0	0	39	0
7	1	0	4	2	3	39	0
14	3	0	12	3	3	50	0
28	—	—	—	—	—	46	0
35	—	—	—	—	—	46	0

Following the 45-minute exposure the larvae were removed and placed into clean petri dishes containing a small amount of dog food. The number of survivors were determined at intervals of 24 hours, 1 week, and 2 weeks for all treatments. For Diazinon an additional reading was made at 4 and 5 weeks. Not one of the insecticides at the maximum dosages used as a residual treatment gave satisfactory control (table 3). The results using DDT agree favorably with those of Fulton *et al.* (1949) and Walchli (1955) who reported that carpet beetles had a natural resistance to DDT. Because of the natural resistance of carpet beetles to 5% DDT and the ineffectiveness of 5% methoxychlor, 2% chlordane, 1.25% lindane, 0.5% dieldrin, and 0.5% Diazinon, these chemicals were not considered satisfactory for controlling carpet beetles by residual sprays.

Cloth Impregnation.—Woolen cloth imgregnated with some insecticide protects the fabric by repelling the insects or most often by killing the invading clothes moth or carpet beetle larvae. The insects are killed by the impregnated insecticide functioning as a stomach or contact poison or possibly as a fumigant. Most often the effective action of the insecticide is due to its combined stomach and contact effect (Walchli 1955).

Experiments using DDT (5%) and chlordane (2%) to treat woolens as recommended by the U. S. Department of Agriculture (Anon. 1955a) were found effective in killing the relatively resistant carpet beetle larvae when exposed continuously to the treated wool in petri dishes. Woolens treated with chlordane must be dry cleaned after storage (Anon. 1955b) because chlordane is relatively toxic and is readily absorbed through the skin (Von Oettinger 1955). Precautions should be taken when using any of these insecticides on infant apparel because infants and young children frequently suck and chew their clothes and blankets. Home laundering as suggested in Bulletin No. 24 (Anon. 1955a) does not seem adequate since only about 20 to 60% of an insecticide such as DDT is removed at one washing (Goodall *et al.* 1946).

DISCUSSION.—The protection of woolen clothes placed in storage in closets and trunks against insect damage may be accomplished by various means. The technique has to be effective against common carpet beetles in order to provide satisfactory protection, because extensive records show that the carpet beetle causes more damage to stored woolens in home than the clothes moth.

The control techniques discussed in this paper are classified as barriers, fumigation, residual spray treatment, and cloth impregnation. The results obtained using the fumigation and residual spray techniques are unsatisfactory against the carpet beetle. Both the use of barriers and cloth impregnation were effective in protecting woolens against carpet beetles. Of these two methods the barrier technique is considered more satisfactory than cloth impregnation for the following reasons:

(a) It is simpler to place clothes in plastic bags or other insect-tight containers than handling and spraying the clothing. Also Davis (1946) appropriately suggests that he doubts that homemakers would make correct applications in impregnating the woolens.
(b) It is more economical because only one dry cleaning is required with the barrier technique whereas two are usually required with the cloth impregnation technique.
(c) Any possible toxicity dangers are avoided.
(d) It is effective for long periods of time.

The most satisfactory technique for homemakers to employ for protecting their woolens from fabric pests is appropriately described by Davis (1946) was follows: "No chemical has the good results obtainable by clean-up of breeding places, dry cleaning (without the use of so-called moth-proofing chemicals) and proper storage."

REFERENCES CITED

Anonymous. 1955a. Clothes moths and carpet beetles—how to control them. U. S. Dept. Agric. Home and Garden Bull. **24.**

Anonymous. 1955b. Interpretation with respect to labeling of household insecticides containing chlordane. Code of Fed. Regulations, Title 7B, Chapter III, Section 362.117.

Arnold, J. W. 1957. Toxicity and repellancy of paradichlorobenzene to larvae of the black carpet beetle. Jour. Econ. Ent. **50**(4): 469–71.

Arnold, J. W. 1953. Para and naptha as closet fumigants. Soap and Sant. Chem. **29**(8): 134–41, 155.

Bateman, E., and R. Baechler. 1937. Some toxicity data and their practical significance. Proc. Amer. Wood. Preservers' Assoc. Jan. 91–104.

Davis, J. J. 1946. DDT to control household and stored grain insects. Jour. Econ. Ent. **39**(1): 59–61.

Fulton, R. A., and O. C. McBride and W. N. Sullivan. 1949. Toxicity residues from carbon dioxide-propelled insecticides. Jour. Econ. Ent. **92**(1): 123–6.

Furry, M. S., H. M. Robinson, and H. Humfield, 1941. Mildew resistant treatments on fabrics. Indust. and Engineer. Chem. **33:** 538–45.

Goodall, F. L., T. F. Gorton and J. V. Summersgill. 1946. DDT and its textile applications. Jour. Soc. Dy. Col. **62:** 189–98.

Harvey, W. C., and H. Hill. 1947. Insect Pests. K. H. Lewis, London, 347 pp.

Imamura, S. 1935. On the olfactory and visual senses of *Anthrenus verbasci* L. (Dermestidae). (In Japanese) Seric. Expt. Sta. Japan. Bull. **9:** 1–21.

Klotz, L. J. 1936. Nitrogen trichloride and other gases as fungicides. Hilgardia **10:** 27–52.

Molnar, N. M. 1947. A new mothproofing larvacide. Soap and Sant. Chem. **23**(7): 143, 145, 147, 149.

Moncrieff, R. W. 1950. Mothproofing. L. Hill, Ltd., London. 200.

Nachman, M. B. 1958. The orientation within the habitat and the search for food of *Tineola bisselliella* Hummel. M.S. Thesis. Cornell University, Ithaca, New York.

Scott, E. W., W. S. Abott, and J. E. Dudley, Jr. 1918. Results of experiments with miscellaneous substances against bed bugs, cockroaches, clothes moths, and carpet beetles. U. S. Dept. Agric. Bull. **707.**

Von Oeitingen, W. F. 1955. The halogenated hydrocarbons—toxicity and potential dangers. U. S. Publ. Health Serv. Publ. **414.** U. S. Govt. Print. Off., Washington. 430 pp.

Walchli, O. 1955. Die Anwendung von DDT-Insektiziden in Textilschutz., DDT. P. Muller, Ed. Birkhauser Verlag, Basel. 299 pp.

Polyhedral Bodies from Diseased Pupae of *Anisota senatoria* (J. E. Smith)[1]

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The orange-striped oakworm (*Anisota senatoria* (J. E. Smith)) occurred in southeastern Connecticut during the summer of 1958 in unprecedented numbers (Hitchcock 1958). In numerous areas extremely dense populations developed, and the larvae rapidly exhausted their food supply. Where this occurred, they were subjected to intense competition, starvation, and were forced to feed on unfavorable foliage. These populations were observed at weekly intervals for signs of disease.

In one such area at Glastonbury, Connecticut, heavy mortality developed among late instar larvae during the last week in August. Larvae were collected for observation in the laboratory, and dead larvae collected for pathologic examination. It could not be determined in the field if the heavy mortality was due to starvation and desiccation or if a cytoplasmic polyhedral virus disease was present. The larvae ceased feeding and migrating, died, their bodies became flabby, and they gradually dried up in a manner suggesting the cytoplasmic virus. No typical signs of nuclear polyhedral disease were observed.

However, when larvae were transferred to the laboratory and offered fresh white oak foliage, many resumed feeding, the daily mortality rate declined, and eventually several dozen pupae were obtained. While checking the vitality of these pupae, the first clear-cut sign of polyhedral disease was noted. From three of the dead pupae there was leakage of a grey liquid and the entire contents of the pupae were liquified. In microscopic examination of smear preparations of this fluid, large numbers of characteristic polyhedral bodies were observed. Therefore, dead pupae were left for several days suspended in tap water in Erlenmeyer flasks until a white layer of sediment accumulated in the bottom. This sediment was collected, resuspended in tap water and centrifuged three times for washing and purification, and then allowed to dry. The sediment was finally obtained as a white powder which was microscopically indistinguishable from other polyhedral body preparations (polyhedra from gypsy moth larvae).

While it is not possible to say that polyhedral virus disease accounted for the widespread mortality observed among the larval population, signs of the polyhedrosis were observed in dead pupae, and it is the purpose of this note to report the recovery of polyhedral bodies from the pupae of *Anisota senatoria*.

REFERENCE CITED

Hitchcock, S. W. 1958. The orange-striped oakworm. The Connecticut Agric. Expt. Sta. Circ. **204.**

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Evaluation of Insecticides for Lygus Bug Control and Their Effect on Predators and Pollinators[1]

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ABSTRACT

A laboratory method involving the use of caged carrot seed heads was evolved to study the effectiveness of new insecticides and insecticidal combinations for lygus bug control. These laboratory tests showed that DDT or toxaphene combined with Dipterex or malathion resulted in quicker lygus bug mortality and lasted for a longer period of time than each insecticide did when used alone. Malathion and Dipterex alone resulted in satisfactory lygus bug control, but they were not as long lasting as DDT. Bayer 19639, Thiodan, demeton, endrin, and a combination of DDT-Trithion were identified as new treatments of potential value against this pest by means of the laboratory tests.

Replicated plots and aircraft applications in fields of seed carrots showed that DDT was satisfactory for lygus bug control in this area. DDT did not appreciably reduce numbers of honeybees or cause a buildup of red spiders. Dipterex and malathion resulted in satisfactory lygus bug control, caused no spider mite buildup, but did not last as long as DDT and were of no advantage for use on the carrot seed crop.

Under the conditions of these experiments, DDT-Dipterex was the only new treatment indicated as a possible substitute for DDT or toxaphene for lygus bug control. This combination treatment significantly increased mortality over that of DDT, did not induce a buildup of spider mites, or reduce numbers of honeybees. The toxaphene-Dipterex combination was also significantly more toxic to lygus bugs than DDT. However, this combination, as well as toxaphene-malathion and DDT-malathion combinations, caused a spider mite buildup; and they were highly toxic to the predaceous insects present in carrots grown for seed.

Data from field trials on carrot seed crops showed that it was advisable to evaluate new treatments in terms of their effect on beneficial insects as well as on the lygus bugs.

A definite need for a more effective insecticide, or combination of insecticides, to control lygus bugs has developed during the past few years. Several recent reports have indicated an increase in tolerance of lygus bugs, especially *Lygus hesperus* Knight, to both DDT and toxaphene. Menke (1954) first reported indications of lygus bug resistance to DDT on the alfalfa seed crop in Washington State. Andres *et al.* (1955), reporting on their laboratory and field experiments with alfalfa seed in northern California, found some degree of resistance of lygus bugs to DDT, but their results indicated it was of low order. They reported that the lygus bugs from alfalfa seed fields at harvest time were three to four times as tolerant as they were at the beginning of the seed season.

Hills *et al.* (1956) also presented evidence of lygus bug resistance to DDT on sugar beets grown for seed in Arizona. They reported a definitely shorter period of effectiveness against lygus bugs for DDT in sugar beets, and that this resistance was probably due to applications of DDT to adjacent cotton fields. They reported that toxaphene resulted in better control than DDT, but that two applications of DDT were still adequate for control. Anderson & Tufts (1952) indicated that, in southern California, only toxaphene afforded effective lygus bug control during periods of high temperature.

The detection of resistance of lygus bugs to DDT has intensified the search for other effective insecticides. In the areas where resistance has been reported it has been possible to suggest only toxaphene as a substitute. Optional materials that are as effective as DDT and that also have a low order of toxicity to predators, parasites, and honeybees or other pollinators of seed crops are not easy to find.

Zia-ud-Din (1951) tested a number of insecticides against lygus bugs on Chinese cabbage and celery, and found lindane the most effective and residual. He found DDT, toxaphene, and TDE slow in action and effective for 5 or 6 days, while parathion and chlordane were fast in action and residual for 4 to 6 days. Glick & Lattimore (1954) found that toxaphene-DDT, at 1+0.5 pounds per acre, was the most effective treatment for control on cotton. Other combinations of many chlorinated hydrocarbon insecticides were tested for the control of alfalfa insects in Wisconsin by Medler (1955). His best results were obtained with DDT plus dieldrin for control of lygus bugs and other insect pests.

A more recent report by Harries & Valcarce (1957) on toxicity tests in the laboratory against insects affecting sugar beets grown for seed showed that materials such as Chlorthion and endrin had a greater immediate toxicity to lygus bugs than DDT, Perthane, Strobane, or toxaphene. Their tests also indicated a new trend toward possible protection by the systemic phosphates in the seedling stage (when necessary).

In 1956 the author began a series of laboratory and field investigations on lygus bug control at Davis in the Sacramento valley of California. Evaluations of some of the newer insecticides and combinations of insecticides were made in an attempt to discover a treatment that might be quicker in action and more effective than DDT or toxaphene. Lygus bugs breed and feed so readily on developing carrot seed heads (Carlson 1956) that this crop was selected as particularly suitable for satisfactory comparisons between materials. European workers, Wagn (1954) and Kho & Braak (1956), have also published excellent reports on the use of DDT to control the embryoless seed condition of carrot seed caused by lygus bugs.

A laboratory method was developed at Davis in 1956 to test insecticides by using caged seed heads of potted carrot plants. The laboratory tests were supplemented by small replicated field experiments on the carrot seed crop in the Sacramento Valley during 1957. Airplane trials were instituted later in the season to broaden the scope of the investigations. These experiments included

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several of the newer insecticides and combinations of these with DDT and toxaphene. Both lygus bugs and predaceous bugs were captured and counted to determine the effect on the beneficial predators as well as on the lygus bugs. Several traps were also used in an attempt to determine the effect of a few of the treatments on the pollinators of this seed crop. It was felt that treatments found useful for protecting carrots grown for seed would be useful for controlling lygus bugs on other crops. But the effect of treatments on the various predators and pollinating insects was expected to be peculiar to the carrot seed crop.

LABORATORY TESTS.— *Procedure.*—Carrot stecklings of the Red Core Chantenay variety were dug and transplanted into 8-inch pots in the greenhouse in February. Seed heads were not developed enough for insecticidal tests until the latter part of May, but from then on several tests were run. All of the carrot seed plants had to be thoroughly staked (some were over 6 feet tall), and they were dusted or sprayed in the laboratory.

Dusting was very hard to standardize in the laboratory, and hence was done only in the first test. Furthermore, the dust was easily dislodged so that the seed heads were difficult to handle in the greenhouse. Spraying was done indoors with a small Bean hydraulic spray pump to simulate actual active ingredient per acre on an individual plant basis for each treatment. The plants were placed on a turntable and turned one revolution per treatment. All spraying was done at 50 p.s.i., at 5 seconds per plant, at a distance of 2.5 feet, with a flat *Teejet* nozzle tip #80015 which gave an equivalent of 25 gallons of spray per acre. The correct dosage of active material per acre was obtained by changing concentrations of solutions or suspensions as required.

Special small cages made with wire frames and cheesecloth were placed over the carrot seed heads in the greenhouse after treatment. They were 4 inches in diameter and 6 inches long. Both ends had 4 to 5 inches of extra cloth sleeve so that they could be more easily tied around a wad of cotton at top and bottom. This eliminated extra folds that the bugs could get caught in and die unnaturally. The top of each cage was closed with cotton and then tied to a bamboo side-stake. The bottom was tied around the seed stalk which was well protected by the cotton.

Only fertilized, green seed heads were used so that the lygus bugs could feed and oviposit under fairly natural conditions. Only female bugs were used since earlier tests had shown that they survived better than males. It was impossible to produce enough carrot seed plants in the available greenhouse space to provide more than one plant per treatment. Five seed heads per plant were caged for each treatment.

Because of the extreme difficulty and time involved in sweeping, capturing, and caging several hundred lygus bugs the day before each test, only two bugs were used for each of five replications per treatment. Since many bugs were injured in collecting them, each collection was held overnight before individuals were selected for use in tests. When only normal-appearing individuals were used, mortalities did not exceed 10% in the untreated checks. Fresh lygus bugs were introduced into the cages at intervals after treatment. In most of the individual tests the mortalities in the untreated checks were kept low enough so that at least 24- and 48-hour counts could be made. It was very seldom possible to make valid 72-hour counts until the latter part of the season.

Results.—The treatments that were outstanding in comparison with DDT or toxaphene alone are given in table 1 for the first test series. These were: (1) DDT+malathion, (2) toxaphene+malathion, (3) toxaphene+Dipterex, (4) Dipterex, (5) Dipterex+DDT, (6) demeton, and (7) endrin. Parathion was fairly effective and endrin was very effective against lygus bugs, but both are known to be hazardous to apply and very lethal to pollinators and predators. Demeton was also effective and was significantly better than DDT or toxaphene.

Malathion appeared to be about as effective for lygus bugs as DDT, but did not give control for as long a period after treatment. Additional counts were obtained in a few tests at 72 hours after introduction of bugs, and up to 21 or 22 days after treatment. All of them indicated that malathion, DDT, and toxaphene are slow-acting insecticides, giving less than 70 to 80% mortality after 72-hours of continuous exposure. However, all of these materials provide satisfactory control of lygus bugs in practice. There was apparently some type of combined action when the standard chlorinated hydrocarbons were used with malathion or Dipterex. These combinations were observed to be faster in action and to give control of lygus bugs for a longer period of time than any one of the materials when used alone.

The data from the repeated trials shown in table 1 indicate that lygus bugs became increasingly tolerant to insecticides as the season progressed, as also mentioned by Andres *et al.* (1955). This was shown by a decrease in lygus bug mortality of 30% for DDT, a decrease of 40% for Dipterex and a decrease of 25% for Dipterex plus DDT.

The relative effectiveness of insecticides tested on lygus bugs in a second series of laboratory experiments is shown in table 2. The standard treatment of 1-pound per acre of

Table 1.—Numbers of dead lygus bugs obtained after 48-hour exposures to carrot seed heads treated in the laboratory with various pesticides.[a] Davis, Calif. 1956.

TREATMENT AND LB./A.	AVERAGE NO. OF DEAD BUGS
Experiment 1, June 6	
Untreated	0.4
Lindane, 0.5	1.0
Lindane, 0.5+malathion, 1	2.8
Parathion, 1	3.0
Demeton, 0.5	3.2
DDT, 1	2.0
DDT, 1+malathion, 1	3.6
Malathion, 1	2.8
L.S.D. at 5% level	1.1
at 1% level	1.5
Experiment 2, July 16	
Untreated	0.0
DDT, 1	1.8
DDT, 1+malathion, 1	3.8
Malathion, 1	1.8
Ethion, 1	2.2
Guthion, 1	2.6
Thiodan, 1	2.2
Dipterex, 1	3.8
Diazinon, 1	1.8
Endrin, 0.5	3.6
L.S.D. at 5% level	0.5
at 1% level	0.7

TREATMENT AND LB./A.	AVERAGE NO. OF DEAD BUGS
Experiment 3, August 22	
Untreated	0.2
DDT, 1+malathion, 1	2.8
Dipterex, 1	3.4
DDT, 1+Dipterex, 1	3.6
Toxaphene, 1	1.4
Toxaphene, 1+malathion, 1	3.6
Toxaphene, 1+Dipterex, 1	4.0
L.S.D. at 5% level	0.9
at 1% level	1.2
Experiment 4, September 24	
Untreated	0.4
DDT, 1	0.8
Dipterex, 1	2.2
DDT, 1+Dipterex, 1	2.6
Trithion, 1	0.8
L.S.D. at 5% level	1.1
at 1% level	1.5

[a] Based on two tests in which four bugs were exposed to each treatment.

Table 2.—**Number of dead lygus bugs obtained after 48-hour exposures to carrot seed heads treated in the laboratory with various pesticides.[a] Davis, Calif. 1957.**

Treatment and Lb./A.	Average No. of Dead Bugs
Experiment 1, May 11	
Untreated	0.4
Toxaphene, 4	6.0
Bayer 19639, 4	5.8
Bayer 19639, 4 (Soil drench)	1.4
L.S.D. at 5%	0.7
at 1%	1.1
Experiment 2 June 6	
Untreated	0.4
Dipterex, 1	4.4
Dibrom, 1	0.4
Chipman R-6199, 1	3.4
Malathion, 1	3.6
L.S.D. at 5%	1.1
at 1%	1.5
Experiment 3, June 27	
Untreated	0.2
Dipterex, 1	6.0
Bayer 19639, 4	6.0
CP 10516, 1[b]	3.8
CP10502, 1[c]	5.2
Bayer 19639, 1	5.0
Thiodan, 1	5.8
Toxaphene, 1	4.6
L.S.D. at 5%	1.3
at 1%	1.7
Experiment 4, July 24	
Untreated	0.0
Dipterex, 1	6.0
DDT, 1	3.4
DDT, 1+Dipterex, 1	5.6
DDT, 0.5+Dipterex, .05	4.6
DDT, 1+Trithion, 1	4.4
Trithion, 1	4.0
L.S.D. at 5%	1.3
at 1%	1.8

[a] Based on three tests in which six bugs were exposed to each treatment.
[b] Monsanto Chemical Co., 1-(Diethoxyphosphinyl) vinyl dimethyl phosphate.
[c] Monsanto Chemical Co., 1-(Dimethoxyphosphinyl) vinyl dimethyl phosphate.

toxaphene gave better control of lygus bugs than the corresponding treatment with DDT. Applications of DDT and malathion resulted in mortalities comparable to those obtained in the first series (table 1), and confirmed their slowness of action, but acceptable mortality, over a 12-day period.

Dipterex again gave very good control for about 15 days, which was approximately the effective period of the standard materials. Interestingly enough, 0.5 pound of DDT combined with 0.5 pound of Dipterex was superior to DDT, toxaphene, or malathion when each was applied alone at 1 pound per acre. The combination of 1 pound of DDT plus 1 pound of Dipterex per acre again afforded excellent control under greenhouse conditions.

Of the newer materials, Bayer 19639 and Thiodan appeared to be effective against lygus bugs and, in one test, gave good aphid control also. A combination of DDT-Trithion also has merit and could possibly afford control of aphids and spiders mites as well as lygus bugs. Trithion and Chipman R-6199 (Tetram), each used alone at 1 pound per acre gave only fair control. Dibrom (RE-4355),*O,O*-dimethyl-*O*-(1,2-dibromo-2,2-dichloroethyl) phosphate, resulted in poor control of lygus bugs.

The performance of Bayer 19639 at 1 pound per acre remained questionable and should be evaluated further. The 4-pound dosages of Bayer 19639 and toxaphene were very effective against lygus bugs, but these amounts are excessive and the former material is phytotoxic at this rate.

The soil drench treatment with Bayer 19639 at 4 pounds per acre resulted in a low average mortality of lygus bugs 2 days after treatment. The plants treated with this material became increasingly toxic to test bugs by the 12th day. The trend reported by Harries & Valcarce (1957) is thus substantiated, and further work with systemic insecticides seems justifiable.

FIELD EXPERIMENTS.—*Procedure.*—Carrot stecklings of the Gold Spike variety were transplanted into the field in December, 1956, for small replicated field-plot studies on lygus bug control, predator and pollinator relationships. These carrot seed plants were used for the field experiments in 1957. Ten treatments of five replications each were arranged in a randomized block design. Only two rows of staked plants per replication were treated. Three buffer rows were left between each replication to perpetuate and build up the lygus bug infestation.

Insecticidal dusts were applied by hand rotary duster on June 7 and June 21, 1957. Applications unavoidably varied from 40 to 54 pounds per acre. Good coverage was obtained in all cases. Sprays were applied with a knapsack sprayer, equipped with a double set of flat, *Teejet* spray nozzles. Volume, concentration, and time per replication were accurately calculated for each treatment. The first application was delayed until 25% bloom occurred in the third stage seed heads. Usually the initial treatment is applied to seed heads of the second stage. The delay was prompted by an initial low population of lygus bugs. The second application was timed for 25% of bloom in the fourth stage of seed heads.

Lygus bugs, minute pirate bugs, big-eyed bugs, and nabids were collected by shaking individual seed heads into a funnel fastened to a quart jar. With a 2- to 3-foot handle it was possible to reach ahead quickly and far enough to capture the nymphs and adult bugs. Ten seed heads per replication were shaken for each treatment, and the bugs were quickly counted after the jar had been inverted into a box. A differential count of adults and nymphs was made for each species.

The pollinating insects were collected by placing small-cone flytraps over blooming seed heads. These traps were operated in each replication of only four of the treatments (including the check), since setting them up was very time-consuming. They were provided with a cheesecloth top equipped with a cotton plug and were lightly tied to the peduncle of the seed head as well as to the stake. These traps were set up immediately after the treatments were applied and the collections were made by a tube aspirator at intervals that coincided with the day that bug counts were made. These were cumulative collections, and included honeybees as well as flies. After each collection the traps had to be reset over a newly blooming seed head.

Spider mite damage was evaluated 1 day after the final bug count, on July 17, when the seed heads in some of the plots were obviously webbed and damaged. Severity of damage was estimated for 20 seed heads of the third stage per replication. Clean seed heads were rated as zero, light damage as 1, light-to-moderate damage as 2, moderate damage as 3, and severe damage as 4. The index of severity was then calculated for the damaged seed heads in each replication.

Yields were taken from all plots by collecting seed heads from each stage of bloom at the brown-spine stage. Ten seed heads from each replication were collected from the first stage of bloom, 20 from the second, 30 from the third, and 40 from the fourth. After these seed heads were threshed, the seeds were de-spined and cleaned in a Clipper seed cleaner. Each replication for each stage of bloom was weighed separately, and units of 100 seeds were counted and weighed from each lot for germination tests.

Table 3.—Average values obtained from consecutive samplings to determine the effects of various insecticides on populations of several insects on the carrot seed crop, and on crop damage by spider mites. Davis, Calif. 1957.

Treatments	Average Numbers of Adults Plus Nymphs			Average Numbers of Adult Honeybees	Spider Mite Damage[a]	
	Lygus	*Orius*	*Geocoris*		Index of Severity	Per Cent Clean
10% DDT dust	16.0	34.4	7.4	47.6	0.29	76
5% Dipterex dust	13.8	15.2	8.8	35.6	.61	50
10% DDT+5% Dipterex dust	9.2	15.8	5.4	40.8	.36	68
10% DDT+4% malathion dust	12.6	17.2	4.8	—	.92	39
10% toxaphene+4% malathion dust	9.2	13.6	6.0	—	2.06	5
10% toxaphene+5% Dipterex dust	8.0	9.4	4.0	—	.73	46
1 lb. DDT spray per acre	14.6	33.4	6.6	—	.11	89
1 lb. malathion spray per acre	12.2	19.8	8.6	—	.48	55
1 lb. Dipterex spray per acre	22.2	23.0	9.4	—	.28	63
Untreated	57.6	55.4	12.2	61.4	.13	88
L.S.D. at 5%	6.7	9.1	3.7	16.2	.42	—
at 1%	9.0	12.2	5.0	22.8	.56	—

[a] Third-stage seed heads collected from the toxaphene-malathion treatment showed a significant low level decrease in yield due to the spider mite damage; and the germination tests showed a high significant decrease in viability of the spider mite damaged seeds.

It was possible to further test three dust materials in aircraft applications on the carrot seed crop. Plots of 2½ acres each were dusted on June 15, 1957. The counts of lygus bugs and predators were averaged for five subsamples of 10 seed heads each for each treatment, and were based on four consecutive counts up to 24 days after treatment. The values obtained for yield and germination were derived from unit samples of 30 seed heads of the third stage picked from each plot.

Results.—All insect counts, yields, and germination tests for the field plots are summarized in tables 3, 4, and 5. The lygus bugs were *Lygus hesperus* Knight. The minute pirate bugs were *Orius tristicolor* (White). The big-eyed bugs were *Geocoris punctipes* (Say), *G. pallens* Stal, and *G. atricolor* Montandon.[3] The honeybees were the Italian strain of *Apis mellifera* Linn. The spider mites on the carrot seed crop during the 1957 season were *Tetranychus telarius* (L.), the two-spotted spider mite.

The data given in table 3, show that properly-timed DDT dust or spray applications again resulted in satisfactory lygus bug control on carrot seed in the Davis area during 1957. It was the material least toxic to the spider mite predator, *Orius* sp., and possibly for this reason there was no buildup of spider mites in this treatment. Furthermore, in comparison with the check, DDT caused no significant reduction in numbers of honeybees. The 10% DDT dust did cause a significant reduction of the big-eyed bug, *Geocoris* sp., but all data indicated that this predator did not become effective against lygus nymphs until a 1:2 ratio was reached during the first week of July. This was 21 days after the last application of materials and too late for economically satisfactory control. Counts continued in the check plots for an additional 2 weeks showed that a 2:1 ratio was finally achieved. Actually, the numbers of *Geocoris* multiplied while the numbers of lygus bugs decreased. The amount of lygus bug mortality attributable to predators was impossible to determine precisely, however, because plant maturity and the presence of fairly large numbers of crab spiders also affected the pest population. The vagrant crab spiders were *Misumenops californicus* Banks; there were also a few *M. oblongus* Wal., *Erigone* sp., and *Aculepeira* sp.[4]

Malathion or Dipterex when applied alone gave satisfactory initial kill of lygus bugs (about equal to DDT), but both were less residual than DDT. They were less

Table 4.—The effect of several insecticidal treatments for lygus bug control on the yield and germination of carrot seed. Davis, Calif. 1957.

Treatments	Average Weight of One 4th-Stage Seed Head (Gm.)[a]	Average Per Cent Germination			
		First Stage	Second Stage	Third Stage	Fourth Stage
10% DDT dust	0.084	95	93	78	79
5% Dipterex dust	.091	94	93	79	75
10% DDT+5% Dipterex dust	.109	95	94	84	82
10% DDT+4% malathion dust	.101	95	95	78	80
10% toxaphene+4% malathion dust	.075	96	93	85	76
10% toxaphene+5% Dipterex dust	.085	97	94	81	78
DDT spray 1 lb/A.	.089	96	93	82	76
Malathion spray 1 lb./A.	.094	95	95	82	79
Dipterex spray 1 lb./A.	.078	94	91	79	78
Untreated	.069	86	88	75	70
L.S.D. at 5%	.034	3.8	3.7	5.8	8.6
at 1%	.046	5.1	5.0	7.8	11.6

[a] Results of the yields from the first three stages of seed heads were not informative.

[3] All predaceous bugs were identified by Dr. R. I. Sailer, Insect Identification and Parasite Introduction Laboratories, Agricultural Research Service, United States Department of Agriculture.

[4] Determined by Dr. Willis J. Gertsch, American Museum of Natural History, New York, N. Y.

Table 5.—Effects of several insecticidal dusts applied by aircraft on adult plus nymphal *Lygus* and *Orius* on the carrot seed crop and on per cent seed germination. Clarksburg, Calif. 1957.

Dust Treatment	Average Number of Bugs		Per Cent Reduction		Germination of 3rd-Stage Seeds (%)
	Lygus	*Orius*	*Lygus*	*Orius*	
10% DDT	7	39	56	0	91
10% DDT+4% malathion	7	23	56	18	93
10% DDT+5% Dipterex	4	15	74	44	94
Untreated	15	28	—	—	83
L.S.D. at 5%	2.3	5.6	—	—	4.1
at 1%	3.2	7.6	—	—	5.6

toxic to *Geocoris* but caused a greater reduction of *Orius* and honeybees than DDT. For the present, then, there seems to be no advantage in using either of these materials for lygus bug control on carrot seed. Both, however, may be useful when a short residual life of the insecticide is desired. The dust containing 5% of Dipterex was superior to the Dipterex spray. It resulted in a significant increase in the mortality of *Orius*, but produced no spider mite buildup (probably because it is partially effective against spider mites). Compared with DDT, Dipterex was also somewhat more toxic to honeybees but was significantly safer for *Geocoris*.

The combination of 10% DDT plus 5% Dipterex dust was the only new treatment tested that provided significantly more effective lygus bug control than DDT and at the same time did not produce a buildup of spider mites. This combination was significantly more toxic to *Orius* than DDT, but showed benefit in mite control. In addition, this treatment reduced numbers of honeybees only slightly more than DDT, and it resulted in a kill of *Geocoris* about equal to that of DDT.

The 10% toxaphene and 5% Dipterex combination treatment was significantly more toxic to lygus bugs than DDT and appeared to be one of the best of the series tested. However, it also proved to be more toxic to *Geocoris* and *Orius*, and thus allowed a buildup of spider mites. The toxaphene-malathion combination was a little less toxic to lygus bugs and was not quite as toxic to the predators. But this treatment encouraged an even greater buildup of spider mites. DDT-malathion also resulted in a significant spider mite buildup, but was no better than DDT applied alone with respect to control of lygus bugs.

An analysis of variance of the data showed that significantly fewer honeybees were captured in the Dipterex dust treatment than in the check. The DDT-Dipterex combination dust was less toxic than the Dipterex alone, while DDT dust alone did not significantly reduce numbers of honeybees in comparison with the check. The reduction in numbers of bees was probably due to a combination of repellency and mortality; the technique used did not segregate these two factors. However, the reduction in numbers of honeybees was not as great as expected and did not appear to be serious for any of the treatments. These results compare favorably with those obtained by Anderson & Atkins (1958). There was no significant reduction in numbers of the other pollinators present (seed-corn maggot adults, blowflies, or syrphid fly adults) in any of the treatments when compared with the check (data not included in the tables). An increase in the number of syrphid flies captured was recorded 13 and 14 days after both the first and second applications of 5% Dipterex dust. The significance of this is not clear.

Additional computations were carried out in order to segregate mortality percentages for lygus bug adults and nymphs. In the two most effective treatments listed in table 3, DDT-Dipterex and toxaphene-Dipterex, the observed mortality of adults and nymphs were about equal. Adult mortality was 83.4% for DDT-Dipterex and 85.2% for toxaphene-Dipterex. The mortality of nymphs closely approximated these values. Malathion was about equally toxic to adults and nymphs, but gave a significantly lower level of control. The superior results obtained with mixtures of organo-phosphate and chlorinated hydrocarbon insecticides are apparently related to this phenomenon of high toxicity against the adult bugs.

DDT-Dipterex was the only treatment that resulted in a significant increase in seed yield over that in the check for the fourth stage of seed heads (table 4). The seed yields for the first, second, and third stages of seed heads in the treated plots were the same as those in the check and therefore were not included in the table.

All of the treatments increased germination of seed produced by seed heads of the first stage when compared with the check (table 4). DDT-Dipterex, DDT-malathion, toxaphene-Dipterex, and malathion significantly increased germination of seeds obtained from seed heads of the second stage. Germination in seeds of the third stage seed heads was lower; only treatments with DDT-Dipterex and toxaphene-malathion resulted in a very significant increase. Seeds from the fourth stage seed heads were the least viable; treatments with DDT-Dipterex, DDT-malathion, and malathion produced significant increases in germination. The variations in seed germination are consistent with data obtained on control.

The overall correlation of lygus mortality, predator mortalities, effect on pollinators, and effect on spider mites (from field treatments on carrot seed), proved to be a complex but necessary evaluation. The results showed that some of the new materials and combinations were very deleterious to predators and pollinators and that they also increased populations of spider mites.

The data on dusts applied by aircraft, as summarized in table 5, show that the DDT-Dipterex dust provided the best lygus bug control. DDT was again shown to be adequate for controlling lygus bugs, and was the least harmful to *Orius*. No definite advantage was found for the DDT-malathion combination. The reduction of lygus bugs was significantly greater with DDT-Dipterex than with DDT or DDT-malathion. This combination also caused a significant reduction in numbers of *Orius*, but caused no spider mite buildup. All results on yield were nonsignificant and, therefore, are not given. In each of the three treatments there was an increase in percentage germination for the seeds of the third stage seed heads, but there was no difference between treatments.

REFERENCES CITED

Anderson, L. D., and T. O. Tuft. 1952. Toxicity of several new insecticides to honeybees. Jour. Econ. Ent. **45**(3): 466–9.

Anderson, L. D., and E. L. Atkins, Jr. 1958. Toxicity of pesticides to honeybees in laboratory and field tests in southern California, 1955–1956. Jour. Econ. Ent. **51**(1): 103–8.

Andres, Lloyd A., V. E. Burton, Ray F. Smith, and J. E. Swift. 1955. DDT tolerance by lygus bugs on seed alfalfa. Jour. Econ. Ent. **48**(5): 509–13.

Carlson, Elmer C. 1956. Lygus bug injury and control on carrot seed in northern California. Jour. Econ. Ent. **49**(5): 689–96.

Glick, P. A., and W. B. Lattimore. 1954. The relation of insecticides to insect populations in cotton fields. Jour. Econ. Ent. **47**(4): 681–4.

Harries, F. H., and A. C. Valcarce. 1957. Laboratory toxicity tests against insects affecting sugar beets grown for seed. Jour. Econ. Ent. **50**(2): 120–2.

Hills, Orin A., Edgar A. Taylor, and A. C. Valcarce. 1956. Resistance of lygus bugs to DDT on sugar beets grown for seed. Jour. Econ. Ent. **49**(1): 94–5.

Kho, Y. O., and J. P. Braak. 1956. Reduction in the yield and viability of carrot seed in relation to the occurrence of the plant bug, *Lygus campestris* L. Euphytica **5**: 146–56.

Medler, J. T. 1955. Control of common alfalfa insects in Wisconsin. Jour. Econ. Ent. **48**(6): 718–23.

Menke, Herman F. 1954. Indications of lygus resistance to DDT in Washington. Jour. Econ. Ent. **47**(4): 704–5.

Wagn, O. 1954. Bladtaeger (Miridae) og forekomst of fro uden kim hos skaermblomstrede (Umbelliferae). (Miridae and occurrence of embryoless seeds in Umbelliferae). Tidsskr. Planteavl **58**: 58–90.

Zia-ud-Din. 1951. Tests of lindane and other insecticides for control of *Lygus oblineatus*. Jour. Econ. Ent. **44**(5): 773–9.

The Effect of Spray Nozzle Arrangement and Gallonage on Control of the Pink Bollworm and Other Cotton Insects[1]

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ABSTRACT

Yield measurements and infestation estimates of the boll weevil, *Anthonomus grandis* Boh., the bollworm, *Heliothis zea* (Boddie), and the pink bollworm, *Pectinophora gossypiella* (Saunders) were used to evaluate the performance of different spray-nozzle arrangements and gallonages. Results of this study indicate that one number 2 nozzle on 40-inch row centers, delivering 2 gallons of insecticide spray per acre, was as effective as any other nozzle arrangement and gallonage tested. Broad-jet nozzle types appear promising and need additional testing.

Studies by Brown & Hanna (1954) have shown that the boll weevil, *Anthonomus grandis* Boh., and the bollworm, *Heliothis zea* (Boddie), can be controlled by 2 gallons of insecticide spray per acre. Smith & Hanna (1955), and Smith *et al.* (1956) have found that one nozzle directly over each row is as effective as more complex nozzle arrangements in applying sprays to control these same insects. However, measurements of the effectiveness of these spray nozzle arrangements and gallonages on control of the pink bollworm, *Pectinophora gossypiella* (Saunders), were necessary before this information could be incorporated into the recommendations of this station. Studies to obtain these measurements were initiated in 1954 at Port Lavaca and continued in 1955 and 1956 at College Station. Results of these investigations are reported herein.

PROCEDURE.—Nine treatment plots, 0.1 acre in size, were assigned at random in each of four replicated blocks. Yield estimates were obtained from picking areas 0.04 acre in size in the 1954 and 1956 tests, and 0.05 acre in size in the 1955 tests. Adequate buffers were allowed at the sides and ends of each plot to minimize the effects of drift.

Insecticide dusts were applied at the rate of 20 pounds per acre with rotary hand guns. In 1954, insecticide sprays were applied by a tractor-drawn sprayer, and by a high-clearance, self-propelled sprayer in 1955 and 1956. The self-propelled sprayer is similar to that described by Davenport (1956). Insecticide dosages were kept nearly constant by taking calibration measurements in each plot, and making minor adjustments in speed. Applications were made at weekly intervals in 1954 and 1955. Three applications were made in 1954 beginning August 10 and ending August 24. Five applications were made in 1955 from July 9 to August 5. During these years dieldrin-DDT sprays prepared from emulsifiable concentrates were used at the rate 0.3 pound actual dieldrin plus 3.0 pounds of actual DDT per acre. Dust treatments were applied at the same rates as the sprays. Spray mixtures containing 0.4 pound of actual endrin plus 2.0 pounds actual DDT were used in 1956. Fourteen applications were made beginning August 11 and ending October 18.

Infestations of the boll weevil and bollworm were measured in the usual manner. Infestations of the pink bollworm were determined by boll dissection in 1954 and 1955 and by moth emergence in 1956.

Infestation and yield data were analyzed by the acceptable methods, and comparisons between treatment means were made by Snedecor's (1956) modification of Tukey's test. The method for showing significance between treatment means adopted for this report is by the use of the asterisk in the tables.

RESULTS AND DISCUSSION.—Data obtained during 1954 and 1955 are given in table 1. The 1954 test at Port Lavaca was located in late cotton in which boll weevil and bollworm infestations failed to develop. Since the test during 1955 was conducted on cotton in which square formation had ceased, the history of the boll weevil and bollworm infestation was not known; however, this field had received several insecticide applications before being used for experiment. Since the tests were designed solely to obtain information on the pink bollworm, the check plots were treated with endrin or dieldrin as necessary for control of other insects. Tests for significance between treatment means indicate that all DDT treatments in both 1954 and 1955 were equally effective in reducing the pink bollworm populations below those of the check. There were no real differences in mean yields between the DDT treatment and check, or among DDT treatments.

Data obtained in 1956 are presented in table 2. Infestations of the boll weevil and the bollworm indicated that these insects might affect yields. There were no pink bollworm infestation differences. The field used for the in-

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Table 1.—Insect infestation and yield estimates for spray equipment plots given three insecticide applications in 1954 at Port Lavaca and five applications in 1955 at College Station.

Treatment	Nozzles per Row	Gallons per Acre	Pink Bollworm: Mean Per Cent Injured Bolls (Angles) 1954	Pink Bollworm: Mean Per Cent Injured Bolls (Angles) 1955	Pink Bollworm: Mean Mine Population 1954	Pink Bollworm: Mean Mine Population 1955	Yield Mean Pounds Seed Cotton 1954: Per Plot	1954: Per Acre	1955: Per Plot	1955: Per Acre
Check[a]			63.8	67.4	306.9	169.8	29.4	735	68.2	1364
Dust	1		49.1*	47.0*	152.9*	52.5*	32.2	805	72.2	1444
Dust	2		53.1*	35.0*	174.0*	24.8*	31.8	795	70.1	1402
Spray	3 No. 2	6	46.3*	32.2*	137.4*	19.2*	28.7	718	70.0	1400
	3 No. 3	9	51.6*	39.5*	175.1*	29.0*	29.3	732	66.2	1324
	3 No. 6	18	45.4*	36.1*	153.0*	21.2*	29.6	740	65.5	1310
	5 No. 2	10	51.6*	34.0*	215.0*	22.0*	29.3	732	69.2	1384
	5 No. 3	15	49.8*	35.4*	176.9*	28.8*	29.0	725	74.2	1484
	5 No. 6	30	46.1*	33.0*	146.8*	20.2*	32.8	820	68.5	1370

[a] Check received 0.4 lb. actual endrin per acre application in 1955.
* Means differ significantly from check means. There were no differences between any other treatment mean pairs.

vestigation was not ideal because 24 rows were planted several weeks earlier than the remainder of the field, and apparently served as an insect trap. By chance, three of the four plots treated with the "Boom-jet" were in the older cotton which possessed higher insect populations than the other treated plots. Further evaluation of the "Boom-jet" assembly appears necessary, as the mean yields were significantly greater than the mean check yields despite similar insect infestation levels.

All insecticide treatments yielded more cotton than the check plots; but there were no yield differences among insecticide treatments, nozzle arrangements, or gallonages. Increasing the amount of spray to 30 gallons per acre did not result in greater reduction of the pink bollworm population. Simple nozzle arrangements of one nozzle on 40-inch row centers were as efficient as more complex arrangements using drops, and were more economical since fewer nozzles were needed. The elimination of drops also permitted lighter spray-boom construction. If further testing proves the "Boom-jet" assemblies as efficient as booms carrying a nozzle arrangement for each row, the boom could be eliminated, providing even greater saving in construction costs. Spraying at low gallonages was more economical than spray application at the higher rates, since time and labor were saved by handling smaller quantites of water. It appears that much heavier pink bollworm infestations than those occurring in these tests are necessary to cause yield losses.

References Cited

Brown, E. C., and R. L. Hanna. 1954. Amount of spray per acre for the control of cotton boll weevils and bollworms. Texas Agric. Expt. Sta. Prog. Rept. **1687.**

Davenport, M. G. 1956. High-clearance sprayer. Texas Agric. Ext. Service Plan **426.**

Smith, H. P., and R. L. Hanna. 1955. Effects of the type and arrangement of spray nozzles on the control of the cotton bollworm and boll weevil. Texas Agric. Expt. Sta. Prog. Rept. **1752.**

Smith, H. P., C. M. Hohn, and R. L. Hanna. 1956. Effects of spray nozzle types and arrangements on cotton insect control. Texas Agric. Expt. Sta. Prog. Rept. **1906.**

Snedecor, G. W. 1956. Statistical Methods. Fifth Edition. The Iowa State Coll. Press, Ames, Iowa.

Table 2.—Insect infestation and yield estimates for spray equipment plots given 14 insecticide applications during 1956 at College Station.

Treatment Nozzle, Type, and Spacing	Gal. per Acre	Boll Weevil: Mean Per Cent Punctured Squares (Angles)	Bollworm: Mean No. Eggs/100 Terminals	Bollworm: Mean Per Cent Injured (Angles) Squares	Bollworm: Mean Per Cent Injured (Angles) Bolls	Pink Bollworm: Mean No. of Worms Rosette Blooms/Acre	Per 100 Bolls	Per Acre	Yield: Mean Pounds Seed Cotton Per Plot	Per Acre
Check		35.8	43.9	22.3	4.9	1,695	11.1	19,929	45.8	1,145
1, No. 2/row, 40″ on row center	2	11.8	36.4	10.6*	2.5	1,666	1.4	3,267	91.0*	2,275
2, No. 2/row, 20″ on row center	4	10.7	53.0	11.8*	0.0	1,604	0.2	327	90.2*	2,255
3, No. 2/row 20″ on row center drops	6	6.2*	43.5	11.2*	0.0	1,064	0.0	0	89.0*	2,225
2, No. 3/row, 20″ on row center	6	28.0	39.6	14.8	4.5	1,470	1.0	2,940	80.5*	2,012
1, No. 6/row, 40″ on row center	6	10.2	52.3	13.3*	0.0	704	0.1	327	88.0*	2,200
1, Boom-jet, 12 row Swath	11	32.3	40.6	15.0	2.9	1,844	15.6	32,343	67.8*	1,695
2, Field-jet, 6 row Swath each	11	22.3	51.6	16.8	0.0	1,140	11.2	23,522	79.5*	1,988
2, No. 3/row 20″ on row center[a]	6	16.4	51.4	15.8	3.9	1,154	17.4	36,264	80.0*	2,000

[a] Pink bollworm check received 0.4 lb. of actual endrin per acre at each application.
* Means differ significantly from check means. There were no differences between any other treatment mean pairs except that the significant value shown for boll weevil punctures also differs significantly from the "boom-jet" mean.

Control of the Red-necked Peanutworm on Peanuts[1]

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Abstract

Experiments were conducted in Alabama from 1952 through 1956 on population levels of the red-necked peanut worm, *Stegasta basqueella* (Chamb.), damage to peanut plants, control with insecticides, and the relationship of control to peanut yields. Peanuts were heavily infested with larvae during the latter part of the growing season; almost 100% of the buds of untreated plants were damaged. Larvae retarded terminal growth by feeding on the unopened leaflets and on the meristematic region of buds. Three or four applications of 10% DDT, 20% toxaphene, 2% endrin, 2% dieldrin, or 5% Guthion dusts at 20 to 25 pounds per acre per application were highly effective in controlling the red-necked peanutworm. A single application of these insecticidal dusts was helpful in reducing populations. Malathion and heptachlor were less effective against this insect. In the limited number of experiments where yields of peanuts were taken, no significant gains in yield resulted from the control of the red-necked peanutworm.

Larvae of the red-necked peanutworm, *Stegasta basqueella* (Chamb.), were observed feeding on peanuts in Alabama in 1952. Feeding was confined to unopened leaflets of terminal buds. An excellent picture of red-necked peanutworm damage to peanut plants was published by Bissell (1942). Although Bissell found no appreciable damage by this insect, it was reported to be a severe pest of peanuts in Brazil (Bondar 1928).

Experiments were conducted from 1952 through 1956 on population levels of red-necked peanutworm, damage to peanut plants, control with several cholorinated hydrocarbon and organophosphate insecticides, and the relationship of control to peanut yields.

Procedure.—Plots in small-plot field experiments consisted of 4 to 8 rows of peanuts 33.3 feet long with 3-foot alleys between blocks of plots. Treatments were replicated four times in a randomized block design. Insecticidal dusts were applied at 20 to 25 pounds per acre with a rotary hand duster. In large-plot field experiments, plots were 8 to 12 rows wide and 200 to 500 feet long. These plots were separated by 30-foot alleys and each treatment was replicated four times. Dusts were applied at 20 to 25 pounds per acre with a 6- or 8-row tractor-mounted duster. Insecticidal dusts used and application dates are presented in tables giving the results.

Red-necked peanutworm population studies were also made on plants growing in plots treated with soil applications of aldrin, dieldrin or heptachlor granules, or of dusts containing Thimet or Di-Syston® (formerly designated Bayer 19639. *O,O*-diethyl *S*-2-(ethylthio)ethyl phosphorodithionate). The effectiveness of foliage sprays of demeton, schradan, Chlorthion, and methyl demeton were also evaluated.

Infestations of red-necked peanutworms were determined by examining 20 terminal buds selected at random from each plot and counting the number of live worms present. The buds were rated as clean or damaged and the per cent damaged buds was calculated. Yield of peanuts per acre was determined by methods described by Arthur & Arant (1954).

Results and Discussion.—In 1952, larvae of the red-necked peanutworm were observed feeding on late-planted peanuts at the Wiregrass Substation, Headland, Alabama. The first appearance of the larvae in 1953 was on July 8, and in 1954 on May 20. Infestations became heavier during the latter part of each growing season. In several fields of late-planted peanuts, 100% of the terminal buds were infested by September. The larvae fed on unopened leaflets and the meristematic region of buds, which prevented further terminal growth. Usually only one larva was found per bud; however, on occasion as many as five were found. Pupation also occurred in the buds. At least two generations per year were observed.

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Table 1.—Number of red-necked peanutworms and per cent bud damage following application of insecticidal dusts. Headland, Alabama. 1953.

Treatment and Dates of Application[a]	Red-necked Peanutworms per 20 Buds	Damaged Buds
	Sept. 11	Angle[b]
Untreated check	8.0	90.0
DDT-Cu-S 7/17–24, 8/5–20–31	4.3	59.1
Toxaphene-Cu-S 8/31	3.0	69.2
Toxaphene-Cu-S 8/20–31	3.5	63.0
Toxaphene-Cu-S 7/17–24, 8/5–20–31	1.5	40.4
L.S.D. at 5% level	3.7	18.4
at 1% level	ns	29.0

[a] Applied at 20 to 25 pounds per acre per application using 10% DDT or 20% toxaphene in 3.4% metallic copper and approximately 70% sulfur; averaged from four replications.

[b] Percentages transformed to equivalent angles for analysis of variance. (Snedecor 1956).

Table 2.—Number of red-necked peanutworms following application of insecticidal dusts. Headland, Ala. 1953.

Treatment[a]	Red-necked Peanutworms per 20 Buds on Dates Shown	
	Sept. 18	Sept. 24
Untreated	10.8	8.0
DDT—2.5%	6.8	6.3
DDT—10%	4.3	5.0
Dieldrin—2%	5.3	3.5
Endrin—2%	5.3	3.3
Heptachlor—3.75%	9.5	5.8
Malathion—4%	7.0	5.3
Toxaphene—10%	8.0	4.5
Toxaphene—20%	5.0	3.5
L.S.D. at 5% level	4.3	3.6

[a] Insecticidal dusts applied September 15 at 20 to 25 pounds per acre; four replications.

Table 3.—Number of red-necked peanutworms, per cent bud damage and yield of peanuts following application of insecticidal dusts. Headland, Ala. 1954.

Treatment[a]	Red-necked Peanutworms per 20 Buds on Dates Shown				Average	Damaged Buds (Angle[b])	Yield (Lb./A.)
	July 15	July 27	Aug. 4	Aug. 16			
Untreated check	5.5	5.0	5.5	1.5	4.4	82	1068
DDT—2.5%	2.5	3.0	3.0	1.3	2.5	60	924
DDT—10%	1.3	1.0	0.0	0.0	0.6	27	1157
Dieldrin—2%	2.0	1.8	1.8	0.0	1.4	61	1015
Endrin—2%	0.0	1.0	0.0	0.3	0.3	22	1161
Heptachlor—3.75%	2.3	4.0	2.8	1.3	2.6	70	968
Malathion—4%	5.3	5.0	4.8	1.8	4.2	74	989
Toxaphene—10%	4.3	3.0	1.3	2.0	2.7	64	994
Toxaphene—20%	1.5	0.8	0.0	0.5	0.7	36	701
L.S.D. at 5% level	2.1	2.8	1.5	ns	1.2	13	ns
1% level	2.8	3.8	2.1	ns	1.7	18	ns

[a] Insecticidal dusts applied July 7 (rain; 8; 16 (rain); 20; 29 and August 10 at 20 to 25 pounds per acre per application; four replications.
[b] See table 1.

Results of red-necked peanutworm infestation counts made in 1953 on plants treated with DDT-copper-sulfur and toxaphene-copper-sulfur in connection with other insect and disease control studies are given in table 1. Treated plants had significantly fewer worms than the untreated plants, and no significant difference existed between treatments. Significantly less damage to buds occured on treated plants than on those untreated; 5 applications of toxaphene were significantly more effective in preventing bud damage than 5 applications of DDT or 1 application of toxaphene.

In September 1953, examination of 100 buds collected at random from a field of late-planted peanuts revealed that 100% of the buds were damaged and there was an average infestation of 23.2 worms per 20 buds. The effects of a single application of several insecticides on the red-necked peanutworm population are given in table 2. Three days after application of insecticides, plants dusted with 10% DDT, 20% toxaphene, 2% endrin, or 2% dieldrin had significantly fewer red-necked peanutworms than untreated plants. Dieldrin, endrin, and 20% toxaphene were still effective 9 days after treatment.

Results of a duplicate experiment in 1954, begun when 10% of the buds were infested, are shown in table 3. Significantly fewer red-necked peanutworms were found on plants treated with 10% DDT, 20% toxaphene, or 2% endrin than on plants treated with 2.5% DDT, 10% toxaphene, or 3.75% heptachlor (average column, table 3). Malathion was not effective for controlling the red-necked peanutworm. Ten% DDT or 20% toxaphene was more effective in controlling red-necked peanutworms than were corresponding treatments of 2.5% DDT or 10% toxaphene. Neither heptachlor nor malathion was effective in preventing bud damage. Although 2.5% DDT, 10% toxaphene, or 2% dieldrin was effective in preventing bud damage; 10% DDT, 20% toxaphene, or 2% endrin was significantly better. No significant increase in yield of peanuts resulted from control of the red-necked peanutworm.

Results of a large-plot field experiment in 1954 on a field of late planted peanuts having 96% of the terminal buds infested are presented in table 4. All treated plants had significantly fewer red-necked peanutworms than untreated plants (average column, table 4). There was no difference in the effectiveness of 10% DDT, 20% toxaphene, 2% dieldrin, or 2% endrin. Yield increases on treated plants were not significant.

The effectiveness of Guthion dust for control of the red-necked peanutworm was compared with several chlorinated hydrocarbon insecticides (table 5). There was no significant difference between the effects of 5% Guthion and 2% endrin, 2.5% dieldrin, 5 or 10% DDT, or 20% toxaphene dust when applied at 20 to 25 pounds per acre (average column, table 5). Fifteen days after treatment, infestations on all treated plants were significantly lower than those on untreated plants.

Several red-necked peanutworm infestation counts were made on experiments conducted for control of other insects. Four applications of demeton, methyl demeton, schradan, and Chlorthion sprays made to the foliage at monthly intervals throughout the growing season at 0.5

Table 4.—Number of red-necked peanut worms and yield of peanuts following application of insecticidal dusts. Headland, Ala. 1954.

Treatment[a]	Red-necked Peanutworms per 20 Buds on Dates Shown			Average	Yield (Lb./A.)
	Aug. 4	Aug. 16	Sept. 8		
Untreated check	12.5	11.3	3.5	9.1	498
DDT—2.5%	7.5	8.8	2.3	6.2	386
DDT—5%	9.0	7.5	2.3	6.3	377
DDT—10%	6.0	6.8	2.0	4.9	426
Dieldrin—2%	6.3	4.0	2.0	4.1	276
Endrin—2%	2.3	5.8	0.8	3.0	542
Toxaphene—10%	7.5	7.3	3.5	6.1	387
Toxaphene—20%	3.3	3.8	2.3	3.1	396
L.S.D. at 5% level	3.6	3.4	ns	2.8	ns
at 1% level	4.9	4.7	ns	3.8	ns

[a] Insecticidal dusts applied July 29, August 10, and 31 at 20 to 25 pounds per acre per application; four replications.

Table 5.—Average number of red-necked peanutworms following application of insecticidal dusts. Napier Field, Ala. 1956.

Treatment[a]	Red-necked Peanutworms per 20 Buds on Dates Shown			Average
	Aug. 10	Aug. 15	Aug. 22	
Untreated check	12.8	10.0	5.0	9.2
DDT—5%	3.8	3.0	1.3	2.7
DDT—10%	2.3	2.3	0.3	1.6
Dieldrin—2.5%	5.3	3.3	1.8	3.4
Endrin—2%	2.0	1.0	0.0	1.0
Guthion—2.5%	5.5	5.3	1.3	3.9
Guthion—5%	2.5	1.0	0.0	1.2
Toxaphene—20%	2.8	0.5	0.3	1.0
L.S.D. at 5% level	3.3	3.8	1.0	2.3
at 1% level	4.5	5.2	1.4	3.2

[a] Insecticidal dusts applied on August 7 at 20 to 25 pounds per acre; four replications.

pound per acre per application were not effective against the red-necked peanutworm. Aldrin, dieldrin, or heptachlor granules at 2 pounds per acre, or Thimet or Di-Syston dusts at 2.5 or 5 pounds per acre applied to the soil before planting or as a sidedress treatment to the soil were not effective for controlling the red-necked peanutworm.

References Cited

Arthur, B. W., and F. S. Arant. 1954. Effect of systemic insecticides upon certain peanut insects and upon peanuts. Jour. Econ. Ent. **47**(6): 1111–4.

Bissell, T. L. 1942. A micro leaf worm on peanuts. Jour. Econ. Ent. **35**(1): 104.

Bondar, G. 1928. Uma praga do amendoim, *Parastega* (*Gelechia*) *bosqueella* Chambers. Chacaras e Quintais **38**: 490 (Rev. Appl. Ent., Ser. **17**: 159).

Snedecor, G. W. 1956. Statistical Methods. Fifth Edition. Iowa State Coll. Press, Ames, Iowa.

A Survey of Beet Leafhopper Populations on Sugar Beets in the Imperial Valley, California, 1953–1958[1]

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Abstract

During the dry years covered by the survey (1953–57) most of the beet leafhoppers (*Circulifer tenellus* (Baker)) and curly top in the Imperial Valley originated in the cultivated areas. The sugar beet and weeds were the most important host plants. A curly-top outbreak occurred in 1956, a year in which desert populations were low. The beet-leafhopper population and curly-top incidence were greatly reduced in the summer because of the reduction in numbers of host plants. The reduction was increased by establishment of a voluntary beet-free period and a weed host and beet-leafhopper control program. During the comparatively damp season of 1957–58, a moderate population developed in the uncultivated areas, while reproduction was delayed in cultivated areas.

The beet leafhopper, *Circulifer tenellus* (Baker), by transmitting the curly-top disease, has caused serious damage to sugar beets, flax, tomatoes, and other crops in the Imperial Valley, California. The present survey was made to determine the relative importance of beets and other host plants as sources of the beet leafhopper and of curly top in the area. The survey was started at the request of the Imperial Valley district of the California Beet Growers Association to determine whether there were any concentrations of host plants on which the beet leafhopper could be controlled before invading the sugar beets, and whether the sugar-beet season could be safely extended by doing away with the summer beet-free period.

Commercial growing of sugar beets in the area began about 1937, after it had been found that damage from curly top was greatly reduced when beets were planted in October and November and harvested in May and June. A beet-free period was in effect most of the summer. Later, with the development of sugar-beet varieties such as U. S. 56/2, which were more resistant to curly top and better adapted to local conditions (Price *et al.* 1954), many successful plantings were made during the summer. By 1952, an interest had developed in widespread planting during the summer so as to extend the harvest season. However, because of the general prevalence and severity of curly top, early planting was not recommended that year.

In January 1953, the present study of the beet-leafhopper problem was begun. A population survey was made of the beet leafhopper on beets throughout the year. Counts were also made on other host plants in the area that might be primary sources of beet leafhoppers, or that might serve as alternate host plants of the leafhoppers during a beet-free period.

Population counts were made by sweeping sugar beets and other host plants at 2-week intervals for the first 2 years and during critical periods since that time. Counts on beets were made in 20 representative areas in the Valley. Counts were based on the average number of leafhoppers collected in 100 sweeps with a 15-inch sweep net. The Hills' cage (Hills 1933) was used for comparing populations on small seedlings. Limited tests were made of the incidence of curly-top virus from individual field-collected leafhoppers by feeding them on susceptible test beets. Host plants were tested for curly-top infection by transmission tests with noninfective beet leafhoppers.

Beet Leafhopper Populations on Beets.—In the Imperial Valley sugar beets were found to be the most important cultivated host plant of the beet leafhopper. Beets which had escaped from cultivation were included along

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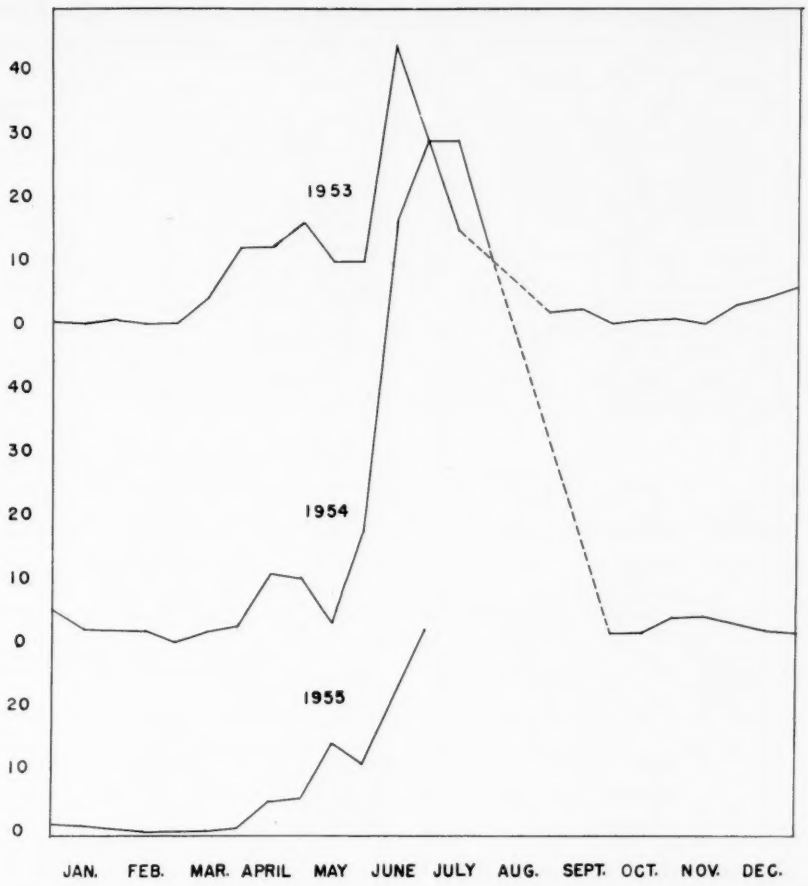

FIG. 1.—Population counts of beet leafhoppers per 100 sweeps on sugar beets in the Imperial Valley, California.

with cultivated beets rather than with weeds in the survey. Nymphs and adults were found on beets throughout the year, and a large population was found to build up on this crop. The typical population cycle for 1953 and 1954 is shown in figure 1.

Sugar beets have usually been planted during the period from September to November, but in 1953, 1954, and 1955 a considerable number were planted before that time. Small beet plants were especially attractive to beet leafhoppers and reproduction proceeded rapidly on these plants while temperatures were high. After August, reproduction slowed down, and few eggs hatched from November to March. The population remained low during this period and there was evidence of movement to the margins of fields and to the more scattered weed and desert hosts. In March, nymphs became abundant and the counts began to rise. During April, May, and June there was a rapid rise in counts. The population peak was reached in May and June, during completion of the beet harvest.

Small seedling beets are particularly susceptible to infection by curly top (Giddings 1954). In addition, curly top is rapidly disseminated on small beets, apparently because the leafhopper is more active as a result of the high temperatures near the exposed soil. Beets planted during the hot season rapidly become infected if the insect vector and the virus are present. In 1953 one field of spring-planted beets showed severe symptoms on 35% of the plants. Experimental plantings in June 1956 rapidly became 100% infected. July plantings in 1953 also were found to be nearly 100% infected. Beets planted in August in 1953, 1954, and 1955 developed 10 to 15% infection in some fields in spite of the fact that these fields were repeatedly dusted with DDT to control caterpillars.

BEET-FREE PERIOD.—The extreme heat and dryness of summer weather in the Imperial Valley decreases the numbers of host plants and shortens the length of life of the beet leafhopper. A beet-free period in July or August was very effective in reducing the numbers of beet leafhoppers. During the past 6 years there has been a great reduction in numbers of leafhoppers at this time, but the reduction was greatest during the year in which the beet-free period was longest and most complete (see table 1).

During the summer there was also a great reduction in the incidence of curly top. This reduction, like that of the leafhopper, was greatest when the beet-free period was longest and most complete. In 1952 there was a long beet-free period which was followed by a low incidence of the disease. In 1953 and 1954 the beet-free period was broken by small beet plantings in July and August. Curly-top incidence increased both years, but was so low that no serious damage occurred. In 1955 the beet harvest season

Table 1.—Beet-leafhopper counts on sugar beets, showing reduction during summer after July.

MONTH	1953	1954	1955	1956	1957	1958
January	0.9	3.4	1.8	9.2	0.4	5.9
February	0.5	1.4	0.7	20.9	0.6	3.0
March	8.8	2.6	0.9	17.4	2.6	8.3
April	14.5	10.8	5.5	235.7	9.4	16.8
May	10.5	10.7	13.0	160.0	23.6	37.3
June	44.6	73.0	32.3	137.8	24.7	249.2
July	15.0	71.0	—[a]	1250.0	—	754.1
August	2.5	—	—	—	—	—
September	0.2	0.1	2.0	—	0.8	—
October	1.3	3.1	2.7	0.4	—	2.4
November	2.4	4.6	—	0.6	3.5	—
December	5.7	2.0	6.0	0.7	4.0	—

[a] Beet harvest season extended to August 3, and many beet fields were planted in July. Note increased abundance of beet leafhoppers in 1956.

Table 2.—Summer counts of the beet leafhopper on host weeds.

HOST PLANT	AVERAGE NUMBER OF LEAFHOPPERS/100 SWEEPS	
	1953	1954
Amaranthus Palmeri	76.1	83.2
Atriplex semibaccata	48.6	44.0
Bassia hyssopifolia	91.8	28.8
Brassica Tournefortii	33.8	166.7
Chenopodium murale	156.9	115.1
Polygonum aviculare	14.2	51.6
Salsola Kali var. *tenuifolia*	10.3	19.6
Sesuvium sessile	14.9	37.2
Sisymbrium Irio	50.1	52.7
Tribulus terrestris	7.7	4.2

was extended to August 3, and many beet fields were planted in July. In addition, a large acreage of beets was grown to feed stock through the summer. As a result there were many infected beets to serve as a source of virus for the fall beet crop. Curly top was found in most fields of fall beets and many of the fields were badly damaged. In the following spring, there was a major curly-top outbreak in the Valley. In August and September 1956, a 40-day beet-free period was carefully maintained and was followed by a year in which curly top was extremely rare. In 1957 the beet-free period was not so complete, and the incidence of curly top in the following beet crop was slightly higher. Even during 1956 and 1957 there were enough escape beets, wild beets, and stock-feed beets to account for most of the carry-over of curly top. In 1958 an increase in beet-leafhopper counts and curly-top incidence over those that occurred in 1956 and 1957 was apparently due to an increase in weed hosts present during the beet-free period.

WEED HOSTS IN IRRIGATED AREAS.—Large numbers of beet leafhoppers were found on weed hosts in irrigated areas. The weed hosts present during the summer were found to be particularly important in maintaining a population of beet leafhoppers between beet crops. During the rest of the year beets were relatively more important than weeds because of the large acreage of beets. During the cooler part of the winter the beet leafhoppers were less common in dense stands of beets and more common on sparse-growing hosts. Since oviposition started earlier on the sparse-growing hosts, a leafhopper population developed earlier on them than on beets.

A small number of weeds were found to be common enough and good enough hosts to be important in the Imperial Valley. The comparative counts of beet leafhoppers on 10 common hosts on which highest counts were obtained in 2 average summers (1953 and 1954) are shown in table 2. The leafhopper is able to live and reproduce on these plants, but the high counts were partly the result of movement from harvested beet fields.

Five-hook Bassia (*Bassia hyssopifolia*) was the most common weed that did not die out during the summer and on which the beet leafhopper was able to live and reproduce. It was fairly common along roadsides, on ditch banks, and in abandoned fields. Population counts on this plant were highest when the beet harvest was being completed, dropped during August, and increased in September and October. The plants died during November. *Bassia* was unusually common during 1955 but was greatly reduced in numbers by a control program in 1956 and 1957. *Bassia* was not listed as a host by Severin and Thomas (1918); it is probably a more recent introduction into the area. *Bassia* was found to be a poor host of curly top.

Goosefoot (*Chenopodium murale*) was probably the best and most common weed host of the beet leafhopper in the Valley. Population counts were usually higher on this plant than on beets. It was common most of the year in the Imperial Valley but died out almost completely during August. Other species of *Chenopodium* were also present and were good host plants. The mustard, *Sisymbrium Irio*, was a common host. Another good mustard host, *Brassica Tournefortii*, was common in the Niland area. The mustards and the chenopodiums rarely lived through August, which contributed to the effectiveness of a beet-free period at that time.

Rough pigweed (*Amaranthus Palmeri*) was a good summer host for the beet leafhopper and was also a host for curly top. It was locally abundant, particularly in some citrus groves. Other less common summer-leafhopper hosts were knotweed (*Polygonum aviculare*), lowland purslane (*Sesuvium sessile*), Russian thistle (*Salsola Kali* var. *tenuifolia*), and puncture vine (*Tribulus terrestris*).

Australian saltbush (*Atriplex semibaccata*) was a perennial weed host of the beet leafhopper in the Valley. It was fairly common along roadsides, but was not found to be a host for curly top. Small numbers of beet leafhoppers were found on *Atriplex lentiformis* and other native perennial species of salt-bush. The beet leafhopper was not found breeding on them and they were not found to be hosts of curly top.

HOST PLANTS ON THE DESERT.—During the survey period, from January 1953 to the fall of 1957, the desert beet-leafhopper population was small, and only a small number moved into the cultivated areas. This was particularly true during 1956, the year of the severe curly-top outbreak. The number of beet leafhoppers breeding on the desert depended upon the number of annual host plants which grew following rains. There was practically no rain in 1956. There were light summer rains in 1955 and 1957 and moderate rains in January of 1954, 1955, and 1957. A small number of leafhoppers developed on

annual host plants which emerged after the rains. During August and October 1957, and February, March, and April 1958, the rainfall was heavier and a larger population developed on the desert than in the previous 5 years. Hatching began after the fall rains and large numbers hatched in February. A control program was conducted in portions of the desert by the State and County Departments of Agriculture in February. Enough rain occurred to delay migration into the cultivated areas until April, but the expected large increase in the desert leafhopper population later did not occur and curly-top incidence in the desert remained low. A low incidence of curly-top damage to flax, tomatoes, and sugar beets was evident by the time the desert vegetation had mostly dried up and the peak of the leafhopper movement was over.

Although the movement of beet leafhoppers from the desert into the cultivated area did not appear to cause immediate widespread curly top in 1958, it did contribute to a population buildup in the area. In January, the beet leafhopper population on sugar beets increased rapidly although only a few nymphs were present. During February and March cool weather occurred and the leafhopper counts were reduced. In April, at about the time of migration from the desert, the population in the cultivated area began to build up at an unusually rapid rate.

CONTROL MEASURES.—The survey indicated that a summer weed-host control and beet-free period would be the most important measure for control of the beet leafhopper and curly top in the cultivated area of the Imperial Valley. Use of insecticides on remaining weed hosts during the beet-free period would increase its effectiveness. Weed-host control and use of insecticides to control beet leafhoppers at other times of the year would have to be done on a large scale to be effective. Large quantities of insecticides were applied to sugar beets during the fall of 1955, but a serious outbreak of curly top occurred the following spring.

Following the 1956 curly-top outbreak, a group of growers met with officials of the University of California, the Imperial County Agricultural Commissioner's Office, the State Department of Agriculture, and sugar processors to discuss the beet-leafhopper problem. A well organized control program was developed. A 40-day beet-free period was agreed upon, extending from July 20 to September 1. A widespread eradication program was conducted against weed hosts during July and August. Weeds along roads and other public areas were sprayed with DDT and diesel oil by the County and State (Armitage & Harper 1957). The beet-free period and weed- and leafhopper-control program in 1956 resulted in extremely effective control of curly top. Control of curly top in 1957 and 1958, while not so good as in 1956, was better than in 1953, 1954 and 1955, when no organized effort was made to maintain a beet-free period or to conduct a weed- and beet-leafhopper-control program.

REFERENCES CITED

Armitage, H. M., and R. W. Harper. 1957. Report on sugar-beet leafhopper-curly-top virus control in California. California Dept. Agric. Bull. **46**: 1–8.

Giddings, N. J. 1954. Relative curly-top resistance of sugar beet varieties in the seedling stage. Proc. Amer. Soc. Sugar Beet Technol. **8**: 197–200.

Hills, O. H. 1933. A new method for collecting samples of insect populations. Jour. Econ. Ent. **26**: 906–10.

Price, C., D. C. Fife, and B. A. Krantz. 1954. Sugar beet planting date studies in Imperial Valley, California. Proc. Amer. Soc. Sugar Beet Technol. **8**: 164–7.

Severin, H. H. P., and W. W. Thomas. 1918. Notes on the beet leafhopper, *Eutettix tenella* Baker. Jour. Econ. Ent. **11**: 308–12.

Studies of Flavors and Odors of Potatoes and Red Kidney Beans Grown in Rotation with Lindane-Treated Red Clover[1]

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ABSTRACT

Medium red clover growing on Chenango silt loam was treated each year for 2 consecutive years for clover root borer control with lindane at the rate of 1 pound per acre. On the subsequent 3 years potatoes of the variety Katahdin and red kidney beans of the variety California Light Red were planted on these plots. Potatoes grown on the plots when tested for flavor and odor were judged "probably-off" to "strongly-off." On the other hand, the red kidney beans were found to be natural or satisfactory in all cases.

BHC and the refined component of it, lindane, have proven very useful for the control of several forage insects (Marshall & Gyrisco 1951, Gyrisco & Marshall 1951). Both BHC and lindane have been found particularly effective against the clover root borer (Marshall *et al.*, 1949; Gyrisco & Marshall 1950). In a paper by Gyrisco & Marshall (1950) a detailed description was given of an experiment located at Ithaca, New York, where 20 varieties of red clover were treated for the control of the clover root borer with 1 pound per acre of lindane applied as a dust.

Since, in New York, dry beans or potatoes frequently are planted following red clover, this experiment was planned to study the effects of lindane on the odor and flavor of these field crops planted in rotation, following the use of lindane for clover root borer control.

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Table 1.—Mean scores given in flavor and odor tests to boiled potatoes of the variety Katahdin grown in a rotation with red clover that had been treated with lindane for clover root borer control. 1951–53. Ithaca, N. Y.

Clover Treatment Prior to First Potato Planting	Mean Scores[a]					
	Odor[b]			Flavor[b]		
	1951	1952	1953	1951	1952	1953
Untreated	—	9.5	10.0	—	9.6	10.0
Lindane dust—1951 cultivated then lindane spray—1952 just prior to potato planting—A	—	6.9	9.6	—	7.5	9.5
Lindane dust—1951 cultivated then lindane spray—1952 just prior to potato planting—A	—	8.9	9.9	—	8.7	9.6
Untreated	9.8	9.8	10.0	10.0	9.8	9.9
Clover treated—1949 and 1950 lindane dust—B	9.1	8.9	9.7	9.3	6.7	9.7
Clover treated—1949 and 1950 lindane dust—B	9.1	6.3	10.0	9.3	5.3	9.6

[a] A score of 10 indicates natural flavor or odor; a score less than 10 indicates a degree of off flavor or odor.

[b] 13, 15 and 24 judges, respectively, on Dec. 19, 1952; Jan. 14, 1953 and Jan. 20, 1954 tasted six samples against a known check. The six samples consisted of 2 untreated samples, 2 A samples and 2 B samples. The mean scores for all the judges are presented for each testing period.

The experiment at Ithaca was located on Chenango gravelly silt loam described by Howe *et al.* (1924) as follows: ". . . brown to yellowish-brown silt loam about 10 inches deep. The upper subsoil is a grayish-brown or gray gritty silt loam somewhat heavier in texture but only slightly more compact than the surface soil, extending to a depth of about 16 inches. Below 16 inches and extending to a depth of 36 inches, the subsoil consists of pebbly or gravelly dark-brown coarse silt loam or loam. The material throughout the soil is devoid of lime carbonate. The soil has moderate supply of organic matter but contains less of this constituent than the Palmyra soils."

In late May, 1951, plots measuring 10 by 15 feet were laid out in duplicate in areas of medium red clover that had been treated once in 1949 and again in 1950 with 1 pound per acre of lindane applied as a dust. See Gyrisco & Marshall (1950). Two untreated plots served as checks.

All the experimental areas were spaded by hand and the soil well worked with a rake. Each of the plots was then split into two smaller subplots, each measuring 5 by 15 feet, one of the sub plots of each split plot was fertilized with a hand-operated fertilizer spreader at the rate of about 2,000 pounds per acre of 5–10–5 fertilizer and planted with potatoes of the variety Katahdin. The other subplot was fertilized in a similar manner at the rate of about 400 pounds per acre of 5–10–5 fertilizer and planted with red kidney beans of the variety California Light Red.

During the growing season, a rotenone-insoluble copper dust was applied to the potatoes and a rotenone dust to the beans to maintain them free of insects and diseases. The plots were hoed and maintained free of weeds until the beans and potatoes were harvested in October. The harvested beans and potatoes were stored at $40° \pm 5°$ F. until odor and flavor tests were conducted later that winter.

On May 26, 1952, all the plots were refitted and planted again to potatoes of the variety Katahdin and to red kidney beans of the variety California Light Red. Additional plots that had been treated with 1 pound of lindane as a dust in 1951 were sprayed in 1952 with 1 pound of the same toxicant just prior to fitting, fertilizing, and planting to potatoes and red kidney beans. As in the previous year, the dry beans and potatoes were harvested and stored until flavor and odor tests were conducted.

Once again on May 25, 1953, the plots were refitted and planted and later cultivated, harvested, and handled as in the previous years.

The stored samples of beans or potatoes were composited between the replicates, subsampled and cooked in individual containers to avoid contamination of the samples. Samples were prepared for tasting merely by boiling them in salted water until cooked. One-half teaspoon of

Table 2.—Mean scores given in flavor and odor tests to boiled red kidney beans of the variety, California Light Red grown in a rotation with red clover that had been treated with lindane for clover root borer control. 1951–53. Ithaca, N. Y.

Clover Treatment Prior to First Bean Planting	Mean Score[a]					
	Odor[b]			Flavor[b]		
	1952	1953A	1953B	1952	1953A	1953B
Untreated	9.8	10.0	10.0	9.3	10.0	10.0
Lindane dust—1951 cultivated then lindane spray—1952 just prior to potato planting—A	9.6	10.0	10.0	9.7	9.2	10.0
Lindane dust—1951 cultivated then lindane spray—1952 just prior to potato planting—A	10.0	10.0	10.0	10.0	9.0	10.0
Untreated	—	10.0	10.0	—	10.0	10.0
Clover treated—1949 and 1950 lindane dust—B	—	9.8	10.0	—	10.0	10.0
Clover treated—1949 and 1950 lindane dust—B	—	9.8	10.0	—	9.8	10.0

[a] A score of 10 indicates natural flavor or odor; a score less than 10 indicates a degree of off flavor or odor.

[b] 24, 10 and 10 judges, respectively, on Jan. 14, 1953, March 10, 1954 and March 12, 1954 tasted six samples against a known check. The six samples consisted of 2 check samples, 2 A samples and 2 B samples. The mean scores for all the judges are presented for each tasting period.

salt was added for each quart of water. No other condiment was added to the water or vegetables prior to tasting. Judging for flavor and odor was done by panels of 10, 13, 15, and 24 experienced judges chosen from the Department of Entomology of the New York State College of Agriculture and the Department of Food and Nutrition of the New York State College of Home Economics at Cornell University. Details of the methods of odor and flavor testing and scoring have been presented in earlier papers (Gyrisco & Burrage 1954, Gyrisco *et al.* 1955).

DISCUSSION.—Under the conditions of these experiments, lindane when used at the rate of 1 pound per acre each year for 2 consecutive years for clover root borer control on red clover growing on a Chenango silt loam gave a flavor and odor to potatoes of the variety Katahdin which was judged "probably-off" to "strongly-off." Both the flavor and odor were judged to be more strongly off or unnatural in 1952 than in 1951. No reason can be suggested for these differences. Potatoes cropped and tested the third year following the last application of lindane were judged to be "natural" or "satisfactory." The addition of 1 pound per acre of lindane as a spray (to previously treated clover sod) just prior to planting also gave an off-flavor and odor to the potatoes. However, these potatoes and beans were not judged any more objectionable than the flavors and odors gotten from a similar amount of lindane applied to clover sod over a 2-year period.

Red kidney beans of the variety California Light Red, on the other hand, grown under the same conditions as the potatoes, were judged to be natural or satisfactory in all cases.

The data seem to suggest that lindane in amounts as high as 1 pound per acre should be used warily on red clover growing on silt loam in a rotation with potatoes However, it would appear that under the same conditions red kidney beans might be planted with safety.

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REFERENCES CITED

Gyrisco, George G., and R. H. Burrage. 1954. Effects of soil treatments with insecticides on plant growth and fruit quality of strawberries. Jour. Econ. Ent. **47**(5): 859–63.

Gyrisco, George G., W. G. Evans, R. H. Burrage, and Alice M. Briant. 1955. Further studies on the effects of soil treatments with insecticides on residues and fruit quality of strawberries. Jour. Econ. Ent. **48**(6): 700–3.

Gyrisco, George G., and D. S. Marshall. 1950. Further investigations on the control of the clover root borer in New York. Jour. Econ. Ent. **43**(1): 82–6.

Gyrisco, George G., and D. S. Marshall. 1951. Further studies of the control of insects of red clover in New York. Jour. Econ. Ent. **44**(5): 785–91.

Howe, Frank B., H. O. Buckman and H. G. Lewis. 1924. Soil survey of Tompkins County, New York. Government Printing Office, Washington: 1567–1622.

Marshall, D. S. and George G. Gyrisco. 1951. Control of the meadow spittlebug on forage crops. Jour. Econ. Ent. **44**(3): 289–93.

Marshall, D. S., L. D. Newsom, George G. Gyrisco, and H. H. Schwardt. 1949. Control of the clover root borer. Jour. Econ. Ent. **42**(2): 315–8.

Ear Fertilization and Japanese Beetle Damage in Sweet Corn[1]

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ABSTRACT

Expression of damage to sweet corn by the Japanese beetle (*Popillia japonica* Newm.) depends on the amount of uninterrupted time available for the pollen to fertilize the ear completely. In Tendermost sweet corn the minimum time is about 8 hours, as compared with 7 hours for field corn. In years of heavy beetle infestation one treatment during silking will suffice if followed by recommended measures for control of the corn earworm (*Heliothis zea* (Boddie)). Light to moderate beetle infestations have no effect on marketable quality of sweet corn.

The populations of the Japanese beetle fluctuate from year to year in southeastern Pennsylvania, depending on such ecological factors as soil temperature and moisture, but maximum populations of any given year coincide fairly well with the silking of sweet corn. In years of heavy beetle population, short, partly filled ears appear at harvest time and are unfit for either marketing or processing. Although the beetles fed on both tassels and silks, the feeding on silks interferes with pollination and fertilization of the ovaries, and is therefore worthy of further consideration. The possible effect on fertilization and subsequent marketable quality of sweet corn at harvest time by beetles feeding on the silks was questioned in some experimental plots in York County. The Japanese beetle population in these plots was believed high enough possibly to interfere with experimental work on corn earworm control.

Japanese beetle damage in field corn has been examined critically by Coon (1946, 1951a) who reported that the time of silk cutting by the beetles in relation to the time the pollen became lodged in the silk was an important factor in damage expression. If pollen fell on field corn silk 7 hours before the silk was cut, a normal ear developed. Because the growth characteristics of sweet corn are approximately the same as those of field corn, it seemed reasonable to expect that a similar period of uninterrupted

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Table 1.—Results of simulated Japanese beetle damage on Tendermost sweet corn.[a]

Hours Between Pollination and Silk Cutting			
4	6	8	Uncut
Weight of Unhusked Ear (gm.)			
142.8 ±6.5	160.9±22.6	193.1± 7.1	183 ±11.7
Weight of Husked Ear (gm.)*			
84.5 ±8.6**	113.7±14.6*	145.2 ±11.4	174.5±30.5
Circumference of Ear (in.)**			
3.92±0.2*	4.5±0.3	4.9 ±0.2	5.2± 0.2
Kerneled Portion of Ear (in.)			
3.43±1.1	5.0± 0.9	5.8 ± 0.2	5.5± 0.4
Length of Cob (in.)			
7.37±0.07	7.2± 0.5	7.45± 0.1	7.3± 0.4

[a] Values are means (with standard deviations) of three replicates. Double and single asterisks indicate significance at the 1% and 5% levels, respectively.

pollination would be necessary for complete fertilization of the ear. Feeding by beetles after this time would presumably have little or no effect on the marketable quality of the ear at harvest time.

METHODS.—A portion of a large field of Tendermost sweet corn on the farm of the D. E. Winebrenner Co. at Hanover, Pennsylvania, was set aside to study the simulated effects of Japanese beetle damage. Following the method of Coon (1946), silks were cut 4, 6, and 8 hours after pollination to give an indication of the amount of uninterrupted time necessary for ears to become completely fertilized. Four treatments, with at least 20 plants in each of three replicates, were marked off in several rows. As the corn approached the silking period, glassine bags were slipped over the tips of the top ears and kraft bags over the tassels. When most of the adjoining plants in the field were in full silk, the glassine bags were removed and the ears pollinated with the pollen in the kraft bags. No attempt was made to regulate the amount of pollen each ear received other than to shake the bag vigorously over the ear. New glassine bags were placed over the ears until the silks were cut in a manner designed to simulate Japanese beetle damage. At that time the bags were removed, the silks cut off at the tip of the husk, and fresh glassine bags placed over the cut ends. The silks were removed from one group of ears 4 hours after pollination, in another after 6 hours, after 8 hours in a third, and left uncut in the fourth.

When the ears had matured to the roasting-ear stage, they were harvested by hand and data were taken on 20 ears in each of the replicates. Data recorded included (1) the weight of the ear unhusked; (2) the weight of the husked ear; (3) the circumference of the ear at the base, or around its widest diameter; (4) the length of the kerneled portion of the ear; and (5) the length of the cob. The data were treated statistically to determine which of the five factors in general showed significant variation due to the cutting of silks. Similar data were taken on sweet corn of the same variety in adjacent fields where Japanese beetles were prevalent to obtain an estimate of natural damage as compared with that produced experimentally.

RESULTS.—The results are summarized in table 1. Three of the five factors showed no significant variations between treatments, *i.e.*, the length of time the ears were allowed to become fertilized. These were the weight of the unhusked ear, the length of the cob, and the length of the kerneled portion. Conversely, the weights of the husked ears showed differences between treatments at the 5% level, while the circumferences of the ears were significantly different between treatments at the 1% level. These significant differences are noted by appropriate asterisks in the "records" column of table 1. The more important of the five factors insofar as marketability was concerned were the weight of the husked ear and the length of the ear-bearing edible kernels of corn. Because of the apparent lack of significantly different values in these treatments, as well as in some others, each factor was reexamined to try to localize the variation. The results of this effort are indicated in table 1 by the asterisks in the body of the table, following the reported means and their standard deviations.

From these differences it is apparent that ears in which fertilization was allowed to progress for only 4 hours were significantly lower in both husked and unhusked weight and were smaller in circumference than ears that were allowed to be fertilized for 6 hours or longer. The weight of the husked ears with 6 hours of fertilization time was significantly less than the weight of those with 8 or more hours of fertilization. The kerneled portions of the ears with interrupted fertilization were in no case significantly different from those allowed to continue with normal fertilization; the length of the cob remained unaffected by shortened periods of fertilization.

Figure 1 shows the results more strikingly than the values in table 1. The center ear in each of the groups of three was chosen to represent the typical appearance of the results of the treatment; the other ears were chosen from the same plots to show some of the variations encountered. Extreme variations were found among individual ears, such as in the length of the kerneled portion, which was measured from the base of the ear to the developed kernel nearest the tip. In addition, only a few kernels on the ear could increase the circumference enough to be misleading when recorded and treated statistically. As the length of time for fertilization was increased from 4 to 6 to 8 hours, the number of fertilized kernels on the ear also increased. At least 8 hours of uninterrupted fertilization were necessary for Tendermost sweet corn to develop well-filled marketable ears.

To determine the effect of silk cutting by beetles under natural conditions, adjoining fields of Tendermost sweet corn were observed and compared with the ears of the above experiment. This comparison showed that the natural damage was negligible and in no way different from the experimental ears with silks cut at 8 hours after pollination. The infestation in these fields was moderate, as judged by the infestation over the county, and no evidence was available to show that any damage resulted from the beetle infestation.

DISCUSSION.—The minimum of 8 hours necessary for adequate fertilization of Tendermost ears is somewhat longer than the 6 to 7 hours required by field corn as reported by Coon (1946). This difference may be due entirely to temperature differences. Perhaps not all varieties of sweet corn will require 8 hours of protection from beetle damage but since Coon (1951b) stated that in periods of heavy Japanese beetle infestation varietal differences in response to beetle damage tended to disappear,

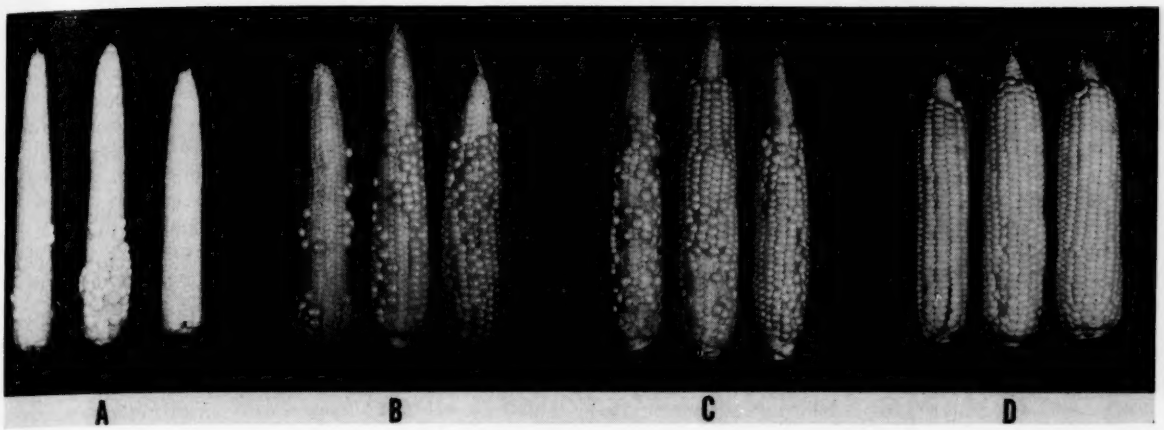

FIG. 1.—Tendermost sweet corn at harvest time. The silks were cut 4 hours (A), 6 hours (B), and 8 hours (C) after pollination. The silks of (D) remained uncut.

it seems safe to assume that these records from Tendermost sweet corn will represent fairly other commercial varieties of sweet corn in this respect.

The comparisons of the experimental results with natural beetle infestation in adjoining fields tend to support field observations that the usual moderate infestation of Japanese beetles in southeastern Pennsylvania experienced in most recent years has little, if any, effect on the marketable quality of sweet corn despite copious feeding on the fresh silks.

In years of heavy infestation, damage is apparent in sweet corn and protection from beetles is advisable. From the above experiments and observations, it can be stated that the silks of sweet corn must be protected from beetles for at least 8 hours after pollination occurs. On a practical basis, this suggests that applications for control might be made twice during the silking period, once when the field reaches the 50% silking level, and another 2 or 3 days later to protect those silks which appear after the first application. This suggested program for beetle control roughly coincides with that planned for corn earworm control, so that if earworm control is exercised, the silks will be sufficiently protected from beetle damage by the addition of one treatment 4 or 5 days prior to the first application usually made for earworm control.

REFERENCES CITED

Coon, B. F. 1946. Duplicating Japanese beetle injury in field corn. Jour. Econ. Ent. **38**(5): 604.

Coon, B. F. 1951a. Well-timed dusting with DDT destroys Jap beetles on corn silks. Science for the Farmer, Suppl. No. 2 to Bull. 529, Pennsylvania Agric. Expt. Sta., March, pp. 3, 9.

Coon, B. F. 1951b. Japanese beetle damage in field corn. Progress Rept. No. 55, Pennsylvania Agric. Expt. Sta., June, 7 pp.

The Effectiveness of Some Insecticides on Several Vegetable Crops[1]

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ABSTRACT

Six insecticides were tested on vegetable crops for phytotoxicity, effectiveness against insects, and effect on flavor and quality of some of the crops. At rates below those usually recommended, Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*,-hexahydro-6,9-methano-2,4,3-benzodioxatheipin-3-oxide), ethion, malathion, Dibrom® (*O,O*-dimethyl-*O*-(1,2-dibromo-2,2-dichloroethyl) phosphate), Sevin® (*N*-methyl-1-naphthyl carbamate), and Trithion® (*S*-(p-chlorophenylthio) methyl *O,O*-diethyl phosphorodithioate) showed no phytotoxicity to cucumber, cantaloupe, tomato, potato, snap bean, lima bean, cabbage, and eggplant. Yields from eggplant and cabbage were significantly increased by sprays of Thiodan, ethion, malathion, Dibrom, and Trithion. Yields of cabbage were significantly increased by Sevin. Yields of tomato, potato, cucumber, and cantaloupe were not significantly increased by any of the insecticides. All materials used were highly effective against the eggplant lace bug, (*Gargaphia solani* Heid.), the margined blister beetle (*Epicauta pestifera* Werner), the cabbage looper (*Trichoplusia ni* (Hbn.)), the imported cabbageworm (*Pieris rapae* (L.)), the potato leafhopper (*Empoasca fabae* (Harris)), and the Mexican bean beetle (*Epilachna varivestis* Muls.). Thiodan was most effective against the cabbage flea beetle (*Phyllotreta cruciferae* (Goeze)) and the corn earworm (*Heliothis zea* (Boddie)). Sevin was effective against the melon aphid (*Aphis gossypii* Glov.) but not the potato aphid (*Macrosiphum solanifolii* (Ashm.)). Trithion and ethion were highly effective against the two-spotted spider mite (*Tetranychus telarius* (L.)). Thiodan and Trithion gave excellent control of the potato aphid. No off-flavors were detected in any of the crops.

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This paper reports experiments carried out in 1957 at the University of Maryland Plant Research Farm near Fairland, Maryland, on the effectiveness of Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*,-hexahydro-6,9-methano-2,4,3-benzodioxatheipin-3-oxide), Trithion®(*S*-(p-chlorophenylthio) methyl *O,O*-diethyl phosphorodithioate), Sevin®(*N*-methyl-1-naphthyl carbamate), ethion, and Dibrom®(*O,O*-dimethyl-*O*-(1,2-dibromo-2,2-dichloroethyl) phosphate) on insect pests of cantaloupe, cucumber, eggplant, tomato, potato, lima bean, snap bean, and cabbage. A malathion treatment and untreated check plots were used in each replication for evaluation of the newer insecticides. The evaluation of insecticides is based on crop yields, reduction of insect populations, phytotoxicity, and flavor and quality of resulting fruit.

METHODS AND MATERIALS.—All insecticides were used in the emulsifiable or miscible form. Spray applications were made with 1- and 3-gallon compressed-air sprayers. The original formulations were based on a desired amount of concentrate in 50 gallons of water (table 1). No attempt was made to apply a given amount of spray at each application, but rather the operator proceeded at a rate normal to him. Careful records of total spray applied were kept, thus enabling the calculation of amount of insecticide actually applied (table 1).

The vegetables used were of the following varieties: eggplant, Black Beauty; potato, Pontiac; cantaloupe, Seneca Delicious; cucumber, Marketer; snap bean, Top Crop; lima bean, Fordhook 242; cabbage, Golden Acre; and tomato, Rutgers. A single row of each vegetable was planted in each 36-×40-foot plot on which treatments were randomized in blocks which were replicated four times. All treatments were applied weekly to all crops from the time the seedlings appeared above the ground or the plants were set in the field until the crops were harvested.

Eggplant received 16 applications of all insecticides, beginning June 24 and continuing until just before the last harvest, October 25, at which time the plants were pulled and weighed. The insect populations on eggplant were estimated by the following methods: computing the percentage of plants infested with *Macrosiphum solanifolii*,[2] rating all the plants as to degree of damage by flea beetles, *Phyllotreta cruciferae*; taking percentage of plants infested with eggplant lace bug; counting corn earworms, and their injury to harvested fruit; and by counting the total number of margined blister beetles. Fruits were counted and weighed at each harvest.

Seven applications of all insecticides were made to cabbage beginning June 24 and continuing until just before the last harvest, July 29. Populations of the cabbage looper, and the imported cabbage-worm were determined by counting the larvae present on all plants of each plot. The percentage of plants infested with the cabbage aphid, *Brevicoryne brassicae* (L.), was determined. Heads were counted, weighed, and rated as to degree of insect injury at harvest.

Cantaloupe received 13 applications of each insecticide beginning June 24. Fruit was harvested twice weekly through September 13, at which time vines were pulled and weighed. Observations were made on percentage of leaves infested with the melon aphid based on leaf samples, one at each 2-foot interval in each row, and on the degree of foliage feeding by miscellaneous insects, principally spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber, and the striped cucumber beetle, *Acalymma vittata* (F.). The percentage of wilted plants was taken in each plot.

Seven applications of all insecticides were made on snap bean beginning June 24. Beans were harvested July 31 and August 7 and 16. Vines were pulled and weighed on the last date. Insect populations were estimated by determining the number of potato leafhopper nymphs on one cotyledonous or fully developed leaf on every other plant in each row of each plot; the number of plants damaged by the Mexican bean beetle in each plot; the percentage of plants infested with the two-spotted spider mite in each plot; by counting the number of leaves damaged by miscellaneous insects, principally blister beetle, spotted cucumber beetle, and green clover worm, *Plathypena scabra* (F.); and determining the percentage of bean pods infested with the corn earworm based on 100-pod samples from each plot. Beans from the first harvest were canned for flavor evaluation.

Lima bean received 11 weekly applications of insecticide beginning June 24. The beans were harvested twice, September 10 and 20, and vines were pulled and weighed September 23. Insect populations were estimated in the same manner as on snap beans. Samples of shelled beans were canned for flavor evaluation.

Potato received 15 applications of all insecticides beginning July 1 until just before harvest on October 28. Blister beetle populations were determined by counting all these insects present on all plants of each plot; potato leafhopper populations were estimated by counting nymphs on one fully developed leaf from each plot. Potatoes from all plots were baked and evaluated for flavor.

On tomato, 15 weekly applications of all treatments were made beginning June 24. Insect populations were estimated by determining the percentage of all plants in each plot infested with aphids, and by determining the percentage of all fruits infested with corn earworm. The incidence of hornworms, *Protoparce quinquemaculata* (Haw.) and *P. sexta* (Johan.), was noted. Tomatoes from each plot were juiced, the juice canned, and the flavors evaluated.

RESULTS.—The average rate of spray application for all treatments with all insecticides was 27 gallons per acre, which resulted in applying less of the active ingredient of each material than was planned (table 1). Observations on the rates of spray application by individuals

[2] Identified by the authors; all other insects and mites were identified by the Agricultural Research Service, Entomology Research Division, of the United States Department of Agriculture.

Table 1.—Average rates of application of all insecticides used in these experiments based on total spray applied to all crops in all plots of each treatment.

Insecticide	Pts. Concentration/ 50 Gal.	Gals. Total Spray Applied	Ml. Total Concentration Used	Lb. Active Ingredient/Gal. Concentrate	Gal. Spray/A. Applied	Average Lb./A. Actual Toxicant
Thiodan	2	44	836	2	29.5	0.28
Ethion	1	42	399	4	28	.28
Sevin	8	34	2,550	1	23	.44
Malathion	2	43	823	5	29	.56
Dibrom	.5	41	204	4	27	.14
Trithion	1	39	372	4	26	.26

Table 2.—Eggplant: Summary of yields, reduction of insect populations and plant injury.

Insecticide	Number Total	Number Increase Over Check (%)	Weight Total	Weight Increase Over Check (%)	Vine Weight (Lb.)	Corn Earworm Fruit Infested (%)	Corn Earworm Per Cent Control	Aphids Plants Infested (%)	Aphids Per Cent Control	Lace Bug Plants Infested (%)	Lace Bug Per Cent Control	Flea Beetle Plants Infested (%)	Flea Beetle Graded Leaf Damage[a]	Flea Beetle Per Cent Control	Blister Beetle Total No.	Blister Beetle Per Cent Control	Flavor Evaluation[b]
Check	291	—	176	—	105.8	17.0	—	38	—	80	—	100	176	—	57	—	3.3
Thiodan	658**[c]	126	485**	176	119.2	.4**	98	6*	84	0**	100	69	50**	71	1**	98	3.3
Ethion	525**	80	378**	114	109.9	10.0	41	31	18	0**	100	100	202	—	0**	100	3.4
Sevin	336	15	171	—	100.5	1.8**	89	100	—	0**	100	100	132*	25	0**	100	3.3
Malathion	425*	46	308**	75	108.9	8.0*	53	46	—	0**	100	100	227	—	0**	100	3.5
Dibrom	480**	65	324**	84	108.3	8.0*	53	40	—	0**	100	100	228	—	4**	93	3.5
Trithion	475**	63	367**	108	102.9	8.0*	53	3*	92	0**	100	99	119**	32	0**	100	3.5

[a] Based on a grade of 4–0, 4 being heaviest damage and 0 being no damage.
[b] Based on 5, better than standard; 4, standard (check); 3, below standard, no noticeable off-flavor; 2, definite off-flavor; and 1, not acceptable.
[c] In this and following tables differences from check significant * at 5% level, ** at 1% level.

have been made for several years (Ditman *et al.* 1957) and will be continued since such information should be of value in making recommendations to home gardeners for effective dilution of insecticides.

Eggplant.—There was no apparent phytotoxic effect of any of the materials used. All plots, except those treated with Sevin, significantly out-yielded the untreated plots (table 2). All insecticides except ethion gave significant reductions of fruit infested with corn earworm; Thiodan and Sevin gave highly significant reductions. Against aphids encountered, only Thiodan and Trithion gave a significant population reduction from untreated plots. All insecticides gave complete control of eggplant lace bugs and all performed well against the blister beetle. Against the cabbage flea beetle, Thiodan, Sevin, and Trithion gave significant reductions of leaf injury. There was no difference in the flavor of the fruit of any of the treatments.

Cabbage.—There was no acute foliage injury by any of the insecticides and no dwarfing of plants. All treatments gave significant increases in yield over the untreated checks. Imported cabbageworm and cabbage looper populations were reduced significantly by all treatments, with malathion and Thiodan giving greatest decreases of cabbage looper. All treatments gave highly significant reductions of aphid populations, the best being obtained by Thiodan and ethion (table 3).

Cantaloupe.—Complete control of the melon aphid was obtained with Thiodan, Sevin, malathion and Trithion; partial control with ethion and Dibrom. Insect injury to foliage was reduced about 35% by Thiodan, Sevin, malathion, and Trithion but was not reduced by ethion or Dibrom. No differences in flavors of fruit were detected.

Cucumber.—There was no acute foliage injury by any of the insecticide formulations used and no apparent dwarfing of plants in any treatment. All treated plots out-yielded the untreated plots both in number and weight of fruit, but differences were not significant. Thiodan, Sevin, Trithion and malathion at the dosages used gave significant reduction of melon aphid populations over untreated plots, but ethion and Dibrom did not. There was no significant difference in the incidence of bacterial wilt (table 4).

Snap Bean.—There was no significant difference in yields of fruit from treated or untreated plots, but vine weights were higher from all treated plots except those treated with Sevin; heavy populations of two-spotted spider mite developed on plots treated with Sevin and completely defoliated and stunted many of the plants. Trithion was the only treatment that completely controlled the spider mites. The incidence of corn earworm and the amount of chewing injury to pods were reduced by all the insecticides used. Trithion, Thiodan and Dibrom gave the highest reduction of injured fruit. All the insecticides showed a high degree of effectiveness against the potato leafhopper, and all significantly reduced plant injury by the Mexican bean beetle. All the chemicals greatly reduced miscellaneous foliage injury which was caused by minor infestations of blister beetle, Colorado potato beetle, *Leptinotarsa decemlineata* (Say), spotted cucumber beetle, and green cloverworm. No significant off-flavors were caused by any of the treatments (table 5).

Lima Bean.—Highest yield was obtained from plots treated with ethion, which in this long-season crop gave greatest reduction in populations of the two-spotted spider mite, though complete control was not obtained

Table 3.—Cabbage: Summary of yields, reduction of insect population and injury to heads at harvest.

Insecticide	Yield Total (Lb.)	Yield Increase Over Check (%)	Cabbage Looper Total No. Observed	Cabbage Looper Per Cent Control	Imported Cabbageworm Total No. Observed	Imported Cabbageworm Per Cent Control	Aphids Plants Infested (%)	Aphids Per Cent Control	Weighted Average Grade of Heads Harvested[a]
Check	75	—	257	—	216	—	100	—	3
Thiodan	138*	84	33**	87	47**	78	9**	91	1.3
Ethion	122**	63	62**	75	21**	90	6**	94	2.4
Sevin	109*	45	79*	69	14**	94	86**	14	2.7
Malathion	129**	72	47**	82	49**	77	25**	75	2
Dibrom	118*	57	73**	72	36**	83	51**	49	1.9
Trithion	110*	47	57**	78	20**	91	25**	75	2.5

[a] Graded on a base of 3, badly damaged; 2, moderately damaged; and 1, lightly or not damaged.

Table 4.—Cucumber: Summary of yields, reduction of insect populations, injury to plants, and incidence of bacterial wilt.

Insecticide	Yield: Number Total	Yield: Number Increase Over Check (%)	Yield: Weight Total	Yield: Weight Increase Over Check (%)	Vine Weight	Aphids: Total Infested Leaves[a]	Aphids: Infested Leaves (%)	Aphids: Per Cent Control	Leaf Damage[b]: Plants Damaged (%)	Leaf Damage[b]: Per Cent Control	Plants Showing Bacterial Wilt (%)
Check	680	—	333	—	119.6	58	72	—	26	—	15
Thiodan	987	45	515	55	146.2	4**	5	93	17	35	13
Ethion	787	16	405	22	119.8	45	56	22	16	38	22
Sevin	743	9	389	17	138.8	7**	8	88	14	46	13
Malathion	857	26	435	31	136.2	11**	13	82	15	42	15
Dibrom	795	17	375	13	127.5	53	66	8	40	—	23
Trithion	739	9	352	6	131.2	6**	7	90	18	31	20

[a] 20 leaves examined on each plot, a total of 80 examined for each treatment.
[b] Mostly feeding by spotted cucumber beetles and striped cucumber beetles.

Table 5.—Snap bean: Summary of yields, reduction of insect populations, and injury.

Insecticide	Yield: Pounds	Yield: Per Cent Increase	Yield: Vine Weight (lb.)	Spider Mite: Per Cent Plants Infested	Spider Mite: Per Cent Control	Corn Earworm: Per Cent Fruit Infested	Corn Earworm: Per Cent Control	Leafhopper: Total No. Observed	Leafhopper: Per Cent Control	Mexican Bean Beetle: Per Cent Plants Infested	Mexican Bean Beetle: Per Cent Control	Leaf Damage: Per Cent Plants Infested	Leaf Damage: Per Cent Control	Flavor Evaluation
Check	38	—	105.0	90	—	7.0	—	245	—	35.0	—	55	—	4
Thiodan	44	12	140.5**	40	55	.7	90	2**	99	2.0**	94	10*	82	4
Ethion	42	11	118.7	10	89	4.5	35	7**	97	1.5**	95	13*	76	4
Sevin	34	—	97.5	96	—	2.0	71	3**	99	.7**	98	13*	76	3.8
Malathion	55	14	132.7*	46	49	3.7	47	2**	99	2.0**	94	20	64	4
Dibrom	38	—	130.2	18	80	1.2	83	12**	95	7.0**	80	12*	78	3.9
Trithion	45	12	130.2	0	100	.7	90	1**	99	3.0**	91	13*	76	3.8

(table 6). Sevin was the least effective material against the spider mite but the most effective against Mexican bean beetle and corn earworm. None of the insecticides affected flavor of canned beans.

Potato.—All treatments gave complete control (population reductions of 99% or better) of the margined blister beetle and the potato leafhoppers with no apparent injury to the plants. There was no off-flavor of potatoes from any treatment.

Tomato.—Observations showed no acute injury by any of the treatments to foliage, no dwarfing of plants, and no significant reduction of fruit. A significantly greater number of fruit was produced on the Thiodan-treated plots, though differences in weight were not significant. Thiodan, Sevin, malathion, and Trithion gave highly significant reductions of corn earworm in the tomato fruits, but ethion and Dibrom showed insignificant decreases from untreated plots. All the treatments showed very significant reductions of potato aphid populations ranging from 34% with ethion to 96% with Trithion (table 7). A few tomato hornworms were present on untreated plots but not in sufficient numbers to record data of significance.

DISCUSSION.—The growing season of 1957 was unusually dry resulting in poor seed germination and irregular stands of snap and lima bean, potato, cucumber, and cantaloupe, which reduced the value of crop yields as a criterion of insecticide performance. The weather was favorable for the development of two-spotted spider mite infestations, which in some instances masked the yield effects of excellent performance of some of the insecticides against other pests. Most satisfactory increases in yields resulting from treatments were obtained with cabbage, which was not attacked by the spider mite, and with eggplant.

Table 6.—Lima bean: Summary of yields and reduction of insect populations.

Insecticide	Yields: Pounds	Yields: Per Cent Increase Over Check	Yields: Vine Weight (lb.)	Spider Mite: Per Cent Plants Infested	Spider Mite: Per Cent Control	Corn Earworm: No. Per 400 Beans	Corn Earworm: Per Cent Beans Infested	Corn Earworm: Per Cent Control	Mexican Bean Beetle: Per Cent Plants Infested	Mexican Bean Beetle: Per Cent Control	Flavor Evaluation
Check	82	—	71.5	90	—	25	6.2	—	83	—	3.9
Thiodan	64	—	65.5	35**	61	3**	.7	88	19**	77	3.8
Ethion	95	14	88.7	9**	90	9*	2.2	64	18**	78	3.9
Sevin	29	—	39.3	90	—	2**	.5	92	8**	90	3.8
Malathion	67	—	76.5	26**	71	8*	2.0	68	18**	78	3.9
Dibrom	61	—	54.5	23*	74	7**	1.7	72	34**	59	4
Trithion	81	—	67.5	15**	83	17	4.2	32	11**	87	3.8

Table 7.—Tomato: Summary of yields and reduction of insect populations.

Insecticide	Yield: Number Total	Yield: Number Increase Over Check (%)	Yield: Weight Total	Yield: Weight Increase Over Check (%)	Vine Weight (Lb.)	Corn Earworm: Per Cent Fruits Infested	Corn Earworm: Per Cent Control	Aphids: Per Cent Plants Infested	Aphids: Per Cent Control	Flavor Evaluation[a]
Check	2902	—	783	—	250.9	19	—	97	—	3.7
Thiodan	3772*	30	1049	34	297.0	3**	84	6**	93	4
Ethion	3391	16	894	14	244.7	18	5	64*	34	4
Sevin	2880	—	723	—	185.3*	6**	68	46*	52	4.6
Malathion	3168	10	845	7	258.6	6**	68	9**	91	3.7
Dibrom	2814	—	735	—	244.6	13	31	64*	34	4.7
Trithion	3671	26	966	23	222.6	7**	63	4**	96	4

[a] On tomato juice.

The effectiveness of the insecticides against the most prevalent pests encountered, which is the most valid means of comparing performance of the different chemicals in this experiment, is summarized in table 8. Two-spotted spider mite was the most difficult to control. At the dosages used, only ethion and Trithion gave 75% or greater reductions (table 8). For evaluation of results on spider mites it should be noted that these plots were in an area where no chemicals had been applied in previous years for control of these pests, so that they had had no opportunity to develop resistance to specific kinds of pesticides.

As can be seen in table 8, only Trithion and Thiodan gave greater than 75% reduction of potato aphids on both eggplant and tomato. All the treatments except Sevin and Dibrom gave a 75% or greater reduction of the cabbage aphid. The melon aphid on cucumber responded well, 75% or greater reductions being obtained with Sevin, malathion, Thiodan, and Trithion. Only Dibrom, which was used at a very low dosage, and ethion gave less than 25% control. However, at rates used, none of the treatments completely eliminated these species of aphids from any plot. Flea beetles were encountered in small numbers during the experiment; however, almost all eggplant showed minor damage from their feeding. Only Thiodan (table 8) gave significant protection while reductions of injury by the other insecticides were 32% or less. All treatments gave high reduction of the margined blister beetle, potato leafhopper, cabbage looper, and the imported cabbageworm.

Thiodan and Trithion gave the greatest relative reduction of all pests encountered. However, at the relatively low dosages applied, neither of these chemicals gave complete control of all the pests, which no doubt would result with slight increases in the amounts used.

Reference

Ditman, L. P., H. B. Owens, and Floyd P. Harrison. 1957. Experiments with sprays, dusts, and aerosols for the home garden. Jour. Econ. Ent. **50**(3): 324–8.

Table 8.—Summary of relative effectiveness of insecticides against the insects and mites on vegetable crops during 1957 at Fairland, Maryland.[a] Each plus equals a 25% or the closest 25% reduction in population or damage.

Insects	Ethion	Sevin	Malathion	Dibrom	Trithion	Thiodan
Macrosiphum solanifolii[b]	+	+	++	+	++++	++++
Phyllotrhta cruciferae	0	+	0	0	+	+++
Gargapeia solani	++++	++++	++++	++++	++++	++++
Heliothis zea[c]	++	+++	++	++	++	++++
Epicauta pestifera[d]	++++	++++	++++	++++	++++	++++
Trichoplusia ni	+++	+++	+++	+++	+++	+++
Pieris rapae	++++	++++	+++	+++	++++	+++
Brevicoryne brassicae	++++	+	+++	++	+++	++++
Aphis gossypii	+	++++	+++	+	++++	++++
Diabrotica undecimpunctata howardi[e]	++	++	++	++	++	++
Acalymma vittata[e]						
Empoasca fabae[f]	++++	++++	++++	++++	++++	++++
Epilachna verivestis[g]	+++	++++	+++	+++	+++	+++
Tetranychus telarius[g]	++++	0	++	+++	++++	++

[a] Each plus sign equals a 25% reduction (or major portion of 25%) in insect population or crop damage
[b] An average between results obtained on eggplants and tomatoes.
[c] An average between results obtained from tomatoes, eggplant, snap bean and lima bean.
[d] An average obtained from results on potato and eggplant.
[e] Included in miscellaneous leaf feeding damage on cucumber and snap bean (tables 4 and 5).
[f] An average obtained from results on potato and snap bean.
[g] An average obtained from results of snap bean and lima bean.

Effectiveness of Thiodan, Sevin, and Lindane on Insects Attacking Freshly Cut Douglas-Fir Logs[1]

D. G. Allen[2] and J. A. Rudinsky[3]

Abstract

Bark of freshly cut Douglas-fir trees (*Pseudotsuga menziesii* (Mirb.) Franco) in the forest was sprayed until runoff with 25% Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) and 25% lindane wettable powders and 50% Sevin® (1-naphthyl N-methyl carbamate) wettable powder, each in dilutions of 1 pound and 3 pounds active ingredient to 100 gallons of water. Lindane was the referent insecticide. All insecticide applications completely protected against insect attack for at least 8 weeks after application except Sevin at 1 pound active ingredient. After 19 weeks no successful attacks of the Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopkins) had occurred on the bark treated with lindane at 3 pounds, or on either of the Thiodan treatments. Sevin at 3 pounds had 0.1 attack per square foot. Lindane at 1 pound had 0.2 attack per square foot. Sevin at 1 pound had 0.4 attack per square foot. Other bark and woodboring insects were proportionately fewer. On the untreated logs there were 2.3 attacks per square foot and they were much more extensive than on the treated logs. In this summary, abortive attacks are ignored. Sap stain and decay fungi were also retarded on treated areas. Termites were absent, although they were present on the untreated logs.

Cut green timber left untreated in the woods during the time of dispersal and attack by destructive forest insects soon becomes infested and degraded. Douglas-fir logs are especially damaged by the Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, by ambrosia beetles (Scolytidae), whose galleries in the wood produce discoloration, by roundheaded and flatheaded borers (Cerambycidae and Buprestidae), which in sufficient numbers may seriously weaken the wood, and by horntails (Siricidae). Harmful fungi usually are introduced by most of these insects and sometimes are the chief damaging agents. An economical control available when logs cannot be removed promptly from the forest would be profitable.

Hetrick & Moses (1953), in testing several insecticides for protection of pine pulpwood against bark beetles, found BHC in water suspension effective, although previously the compound in oil solution had been standard. In his later field tests for protection of freshly cut pine timber, Hetrick (1957) also demonstrated that Sevin® (1-naphthyl N-methyl carbamate) in emulsion gave good protection for about 6 weeks.

During laboratory studies made on contact and residual toxicities of several insecticides to the Douglas-fir beetle (Rudinsky & Terriere 1959) Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3 benzodioxathiepin-3-oxide) and Sevin showed high contact and residual toxicity to that species. These compounds, accordingly, were tested in the field for their effectiveness in protecting freshly cut Douglas-fir logs from damage by the Douglas-fir beetle and other destructive insects. Lindane was the referent insecticide.

Materials and Methods.—Six Douglas-firs, about 105 years old and averaging 21 inches in diameter, were cut on May 7, 1958, in the Marys Peak (Siuslaw National Forest) area, near Corvallis, Oregon. Half the trees were at 300 feet elevation and half at 1,300 feet. To avoid rapid drying, the trees were left entire. On each tree, 6 sections 5 feet long were marked for spraying. Three-foot buffer areas were left between the sections to reduce danger of contamination by drift. Two additional trees per plot were cut for checks.

Test sections of each log were sprayed before insect attack. Thiodan (25%) and lindane (25%) and Sevin (50%) were all used as wettable powders. Two dilutions of each formula were prepared at the rate of 1 pound and 3 pounds of active ingredient to 100 gallons of water. The formulations were applied with 2-gallon, compressed-air sprayers until runoff. Variations in bark texture and thickness from butt to crown were compensated partly by varying order of the six insecticides and their concentrations on each tree and by providing three replicates to a plot. Remaining untreated portions of the upper crowns and boles served as checks in addition to the two check trees on each plot.

In all, 660 square feet of bark were sprayed, or about 110 square feet of bark for each formulation. About 95 milligrams of actual material per square foot of bark were deposited by spray containing 1 pound of chemical to 100 gallons of water, and about 285 milligrams a square foot remained from spray with 3 pounds to 100 gallons of water.

Treated and check trees were examined at intervals for 9 weeks following treatment and again on September 17, nineteen weeks after spraying. At this time, bark was removed from the top sides of the study logs for one-half the circumference of each of the treated sections. During the first 9 weeks, numbers of attacks of Douglas-fir beetles and ambrosia beetles per square foot of bark were recorded periodically on treated sections and on checks. At the last complete examination, number of successful and abortive Douglas-fir beetle and ambrosia beetle attacks per square foot were averaged. Bark area of infestation by flatheaded and roundheaded borers was estimated. Approximate percentages of area visibly invaded by stain and rot fungi also were recorded.

Discussion.—By May 1, 1958, Douglas-fir beetles, ambrosia beetles, and associated insects including clerids, ostomids, cucujids, and a few buprestids and cerambycids were commencing attack where direct sunshine warmed host material. Attacks continued abundantly until May 21, when they were reduced by cool, cloudy weather and more frequent rain. But where warm open-

[1] This paper reports part of the results of an insecticide screening project sponsored jointly by Oregon Forest Lands Research Center, the Oregon Agricultural Experiment Station, the Foundation for American Resource Management and the Northwest Forest Pest Action Council. Accepted for publication December 9, 1958.

[2] Oregon Forest Lands Research Center.

[3] Department of Entomology, Oregon State College.

Table 1.—**Insect attacks and occurrence of visible fungi on Douglas-fir, 19 weeks after freshly cut logs were sprayed with Thiodan, Sevin, and lindane.**

Material (Lb./100 Gal. of Water)	Bark Area Sampled (Sq. Foot)	Average Number of Attacks per Sq. Ft. by				Per Cent Area of	
		Douglas-fir Beetle		Ambrosia Beetles	Buprestids, Cerambycids		
		Successful	Abortive			Sap Stain	Decay Fungi
Lindane, 1	55	0.2[a]	0.5	0.5	very few	30	0
Lindane, 3	56	0.0	0.1	0.0	none	5[b]	0
Thiodan, 1	55	0.0	0.2	0.5	very few	10[b]	0
Thiodan, 3	53	0.0	0.0	0.0	none	5[b]	0
Sevin, 1	56	0.4	0.6	0.7	few	60	5
Sevin, 3	55	0.1[a]	0.2	0.4	very few	30	0
None	80	2.3	0.7	1.6	few	90	40

[a] Beetles in an advanced larval stage, possibly from a second, or summer brood, started in midJuly.
[b] Some sap stain spread under the bark from untreated buffer areas in long, narrow strips.

ings received spotty and occasional sunlight, beetle activity persisted through the cool period, which ended about June 11. This was the case on the experimental plots selected in roadside clearings. Insect activity thus was prolonged for at least 6 weeks until hot, dry weather set in and lasted through July 25. During the hot, dry period, very little activity was recorded. During the first 6 weeks after treatment, some dead Douglas-fir beetles, ambrosia beetles, and buprestids appeared on the bark surface of test logs.

A slight increase in Douglas-fir beetle activity appeared toward the end of July. At this time a few additional attacks apparently occurred on areas sprayed with the 1-pound concentration of lindane and the 3-pound concen-

FIG. 1.—A treated section of log showing long, narrow light-colored strips of fungal invasion restricted in area by failure of the beetles to establish themselves because of toxicity of the spray and possibly by direct toxicity to sap stain and decay fungi. One section of removed bark is lying at the base of the log section.

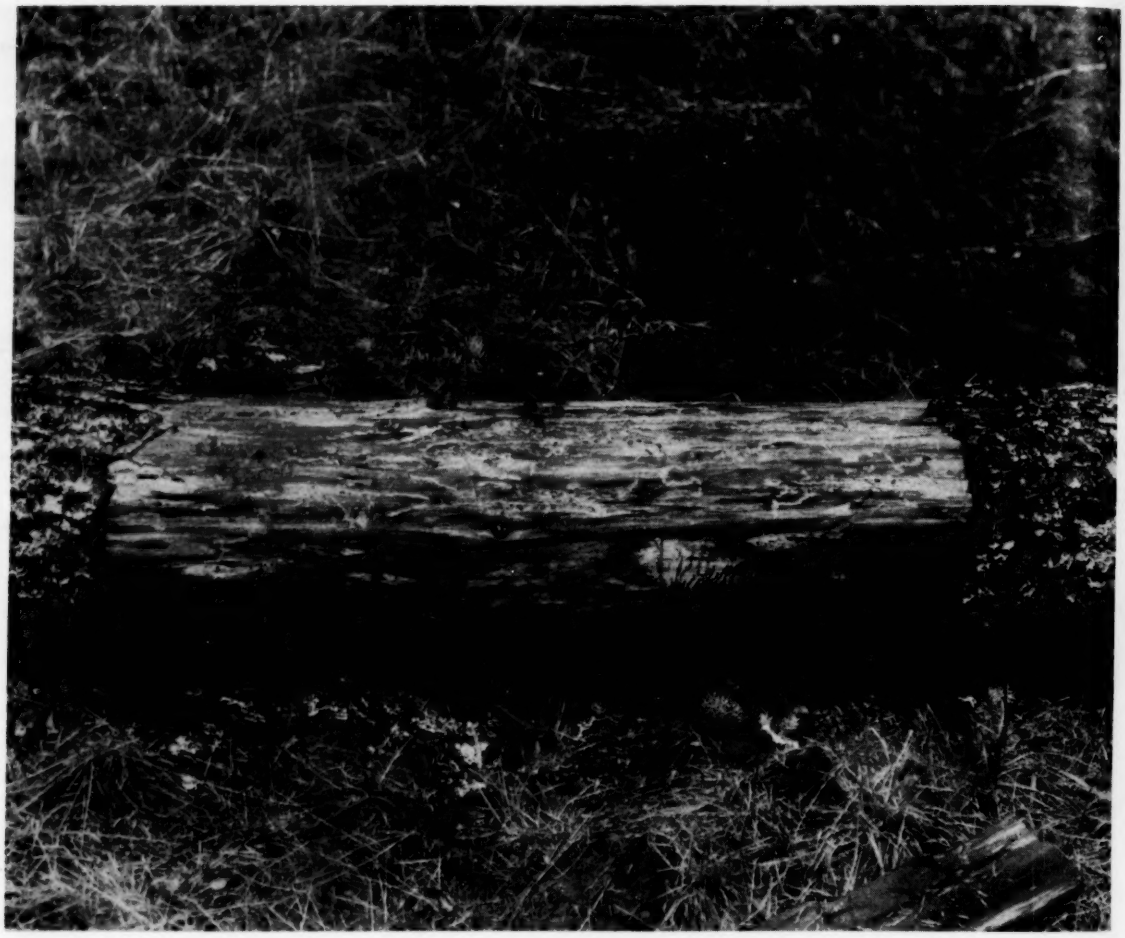

FIG. 2.—An untreated section of log on which the beetles succeeded in establishing themselves and the sap stain and decay fungi were more widely distributed (light area).

tration of Sevin. On last examination, these attacks showed advanced larvae and some callow adults.

Nearly 4 inches of rainfall over the first 7 weeks after spraying were a severe test of residual properties of the insecticides.

RESULTS.—The effectiveness of the three insecticides in protecting freshly cut Douglas-fir trees from attack by Douglas-fir beetles and other insects during the 19 weeks of the test is shown in table 1. Since there was no appreciable difference in the number of attacks per square foot on the two study plots, the results are summarized together. All applications of insecticides provided protection for at least 8 weeks, except Sevin at the rate of 1 pound active ingredient to 100 gallons of water, which allowed some attacks of the Douglas-fir beetle before this time. It should be considered that although there were only 2.3 successful attacks per square foot of bark on the untreated logs, the resulting galleries were 14 to 30 inches long, much longer and more productive than the small, comparatively nonproductive attacks designated successful for treated areas. Most of the galleries in the treated bark produced practically no successful brood.

The treatments also reduced, at least indirectly, spread of sap stain and decay fungi. By September 17, nineteen weeks after spraying, about 90% of the untreated area was covered by fruit bodies of sap stain and about 40% by white mycelial mats of decay fungi. Fungi had penetrated about one-half inch into the sapwood. On sprayed logs the fungi were more restricted (see figs. 1, 2). Also, on the check trees termites were active and incipient damage had commenced, but none was found on treated logs.

REFERENCES CITED

Hetrick, L. A. 1957. Two promising new chemicals for control of insects attacking freshly-cut pine wood. Station to Station Research News, 3(4). Crag Agricultural Chemicals.

Hetrick, L. A., and P. J. Moses. 1953. Value of insecticides for protection of pine pulpwood. Jour. Econ. Ent. 46(1): 160–1.

Rudinsky, J. A., and L. C. Terriere. 1959. Laboratory studies on the relative contact and residual toxicity of ten test insecticides to *Dendroctonus pseudotsugae* Hopk. Jour. Econ. Ent. 52: 485–8.

Laboratory Studies on the Relative Contact and Residual Toxicity of Ten Test Insecticides to *Dendroctonus pseudotsugae* Hopk.[1]

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Abstract

The spray-tunnel application method was adapted for fast determining of the contact toxicity of insecticides to bark beetles. The Douglas-fir beetle (*Dendroctonus pseudotsugae* Hopk.) was used as the test insect. The relative contact toxicity of 10 test insecticides at the LD50 and LD90 levels, listed in decreasing order, was as follows:

at LD50: Lindane>Thiodan®(6,7,8,9,10,10-hexachlor-1,5,5*a*, 6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide)>isodrin>endrin>Sevin® (*N*-methyl-1-naphthyl carbamate)>heptachlor>aldrin and dieldrin>DDT >chlordane;

at LD90: Thiodan>endrin>lindane>isodrin>Sevin>aldrin >heptachlor>dieldrin>DDT>chlordane.

All insecticides showed greater toxicity to the males than to the females except Sevin, which was more toxic to females.

Treated wood fiber surfaces were used for studying the residual toxicity under constant laboratory conditions for a 13-week period. In contrast to the gradual decline in residual toxicity of endrin, Thiodan, and to a lesser degree isodrin, a rapid decrease was shown by lindane, aldrin, heptachlor, and chlordane. DDT exhibited the most gradual decline.

Many of the insecticides currently in use against pests of agricultural plants and animals are still relatively untested against destructive forest insects. Perhaps the primary reason for the neglect of this area of pest control is the difficulty of conducting field tests under forest conditions. Moreover, little has been done to circumvent this problem by means of laboratory testing methods. Moore (1957), has studied the toxicity of several chlorinated hydrocarbons by topical application to *Dendroctonus brevicomis* Lec. and *Ips confusus* (Lec.). The present report describes further work of this type, in which spray-tunnel application was used to determine direct contact toxicity and treated wood fiber surfaces were used to test residual toxicity. Included in the tests were aldrin, chlordane, dieldrin, DDT, endrin, heptachlor, isodrin, lindane, Sevin® (N-methyl-1-naphthyl carbamate) and Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide).

The Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopk., was chosen as the experimental insect not only because it is the most destructive bark beetle of the Douglas-fir forest (Bedard 1950) but also because of its tolerance to insecticides. In preliminary screening tests the Douglas-fir beetle was found to be more tolerant to a number of insecticides than are *Dendroctonus brevicomis* Lec., *Ips oregoni* (Eich.), *Scolytus ventralis* Lec., *S. unispinosus* Lec., *Pseudohylesinus grandis* Sw., and *Phloeosinus punctatus* Lec. Also, basic data on the development of this beetle were already available from earlier studies (Vite & Rudinsky 1957).

The studies reported in this paper were conducted at the Oregon State College Forest Insect Laboratory from January through August of 1958.

Materials and Methods.—The test beetles were obtained from naturally infested Douglas-firs in the vicinity of Corvallis. Infested logs were brought to the laboratory in the late fall of 1957 and stored outside until late spring, when they were transferred to a walk-in cooler at 45°F. The beetles were collected in petri dishes twice daily just before treatment, so that the time between their emergence and the treatment did not exceed 12 hours.

In preliminary trials of various methods for studying contact toxicity, a topical application method was used in which the insect's weight was estimated by visual comparison with previously weighed insects, but the error in estimated weights was considered too great for reliable screening. When insects were weighed on the analytical balance and given the appropriate topical dose, errors were minimal but the time required for the testing was excessive. A compromise between these two extremes was reached when the spray-tunnel method of testing liquid sprays was adopted. In this method (Dorman & Hall 1953) groups of insects are exposed to sprays of differing concentrations. It is assumed that the amount of insecticide that makes contact with each insect is proportional to the body surface and thus to the body weight.

Testing of Sprays.—The test solution was delivered by a nozzle under 8 pounds of pressure into a metal tunnel, 6 inches in diameter and 30 inches long, which exhausted into a hood. Fifteen beetles per batch were placed in a metal cylinder, 3½ inches in diameter and 1½ inches wide, both ends of which were covered by copper screen (18 mesh). The cylinder was then placed on two rollers at the exhaust end of the spray-tunnel and rotated slowly during the application. After 1 milliliter of test solution had been discharged, the cylinder was turned around and a second milliliter was sprayed. Within 10 seconds after the application of the mist, the beetles were transferred to petri dishes and held in a darkened room for mortality counts. A temperature of 68 ± 1°F. and a relative humidity of 70% to 76% were maintained during the mortality observations. Mortality was recorded every 24 hours through 4 days, but dosage-mortality relationship, relative potencies, and other data are based on 72-hour mortality totals. Dead beetles were removed every day and preserved in alcohol for later sex determination and evaluation of possible sex differences in susceptibility.

Test materials were dissolved in a 1:1 mixture of acetone and deobase. All materials tested were analytical

[1] Technical paper No. 1189, Oregon Agricultural Experiment Station. This paper contains part of the results obtained in a research project sponsored jointly by the Oregon State College Agricultural Experiment Station, the Oregon State College Department of Entomology, the Northwest Forest Pest Action Council, the Oregon Forest Protection and Conservation Committee, and aided by the Foundation for American Resource Management. Accepted for publication November 26, 1958.

[2] Acknowledgment is due to R. B. Ryan and L. D. Olinger, graduate assistants, for their help during testing and in the statistical analysis of data.

Table 1.—Dosage mortality relationships 72 hours after treatment of the Douglas-fir beetle with various insecticides.

Concentration (Mg./100 Ml.)	No. of Test Beetles	Per Cent Mortality	Mortality Corrected For Check
	Aldrin		
50	45	27	25
100	30	50	49
250	45	64	63
500	45	98	98
750	45	100	100
checks	105	3	—
	Chlordane		
250	45	31	30
750	45	40	40
1250	45	53	53
1750	45	67	66
2000	45	73	73
checks	65	2	—
	Dieldrin		
50	45	33	32
100	45	47	46
250	45	64	64
500	45	78	77
750	45	93	93
1000	45	100	100
checks	62	2	—
	DDT		
250	60	38	37
500	60	41	40
750	75	58	58
1000	60	73	72
2000	60	85	84
3000	45	91	91
Checks	109	2	—
	Endrin		
25	45	31	28
50	45	73	72
75	30	66	65
100	45	95	95
150	45	100	100
Checks	97	3	—
	Heptachlor		
50	45	33	32
100	30	43	42
250	45	71	70
500	45	91	91
750	45	93	93
1000	30	97	97
1500	45	100	100
Checks	100	2	—
	Isodrin		
12.5	45	20	18
25	45	55	55
50	45	64	64
100	45	78	77
150	30	96	96
200	45	100	100
Checks	99	2	—
	Lindane		
6.25	60	20	17
12.5	60	43	41
25	60	53	52
50	60	63	62
75	60	81	80
100	60	93	93
150	60	100	100
Checks	102	3	—
	Sevin		
25	60	35	33
50	60	43	41
100	45	78	77
150	60	98	98
200	60	100	100
Checks	107	3	—
	Thiodan		
12.5	30	23	21
25	60	46	45
50	60	83	83
100	60	98	98
150	60	100	100
Checks	70	3	—

grade in purity except chlordane, which was technical grade.

Dosage-mortality regression lines were constructed from mortality data obtained when five to eight concentration ranges were tested. Each of the insecticides was tested on at least three different days and with beetles taken from a new population.

RESIDUAL TEST.—Although the spray-tunnel method furnishes useful information on the toxicity of a material, it does not provide an estimate of residual effectiveness. Since many forest insect pests must be controlled by residual deposits on logs and trees, it is important to develop a screening technique that will evaluate residual properties. Bark would be ideal for this purpose if it were sufficiently uniform and could be easily obtained in the proper dimensions. As a substitute, an insulating wall board commonly used in building construction was chosen. This material, Firtex, was cut into 4-inch blocks and treated with wettable powder dispersions of the various materials at the rate of 1.25 grams of active ingredient per 250 mls. of water (0.5%). The wettable powder formulations used were: endrin, heptachlor, isodrin, lindane, and Thiodan, 25%; DDT, dieldrin, and Sevin, 50%; chlordane, 40%; and aldrin, 20%. The spray gun was operated at 15 p.s.i., and the blocks were clipped to a turntable rotating at 7½ r.p.m. Analyses of filter papers similarly sprayed with DDT indicated an average deposit of 40 mgs. per square foot. A sufficient number of blocks were treated to allow the testing of 10 materials at intervals of 2 or 3 weeks during a 13-week test period, each exposure replicated four times. The initial exposure, zero time, was begun immediately after spraying. The exposure tests were conducted by placing the blocks on a turntable rotating at 3 r.p.m. Ten beetles were confined to the treated surface by a covering petri dish. Under these conditions the beetles were in constant motion over the treated surface. After the 5-minute exposure the beetles were returned to clean petri dishes for mortality counts, which were made in the manner previously described. The remaining blocks were held at 77±1°F. pending subsequent tests that were made 2, 4, 6, 9, and 13 weeks after the zero exposure. For construction of the residual toxicity curves during those 13 weeks, mortality after 72 hours was used.

RESULTS.—*Toxicities of Sprays.*—The number of beetles used in each test, the various concentrations of the 10 test insecticides, and the mortality after 72 hours are given in table 1. The order of the toxicity of the insecticides to the Douglas-fir beetle is shown in figure 1. Relative potencies of the toxicants (see Litchfield & Wilcoxon 1949), based on DDT as a standard, and the slope ratios of the regression lines are presented in table 2. Because the regression lines of endrin, Sevin, and Thiodan were not parallel to those of the other toxicants, the dosage-

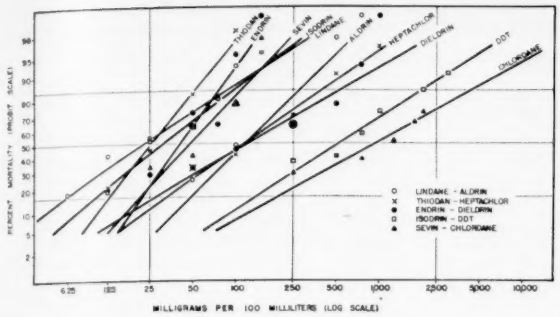

FIG. 1.—Dosage-mortality relationship obtained by spray-tunnel application of test insecticides to the adult of the Douglas-fir beetles.

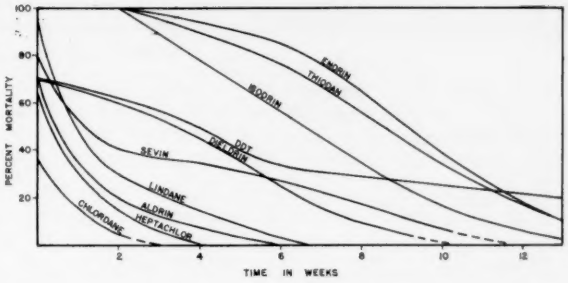

FIG. 2.—Residual effectiveness of the test insecticides against the Douglas-fir beetle exposed to a sprayed wood fiber surface.

mortality values are given at the LD50 as well as at the LD90 levels for all insecticides. At the LD50 level the most toxic insecticide was lindane, while at the LD90 level Thiodan was most effective. The toxicity of the test insecticides at those two levels, listed in decreasing order, was as follows:

at LD50: lindane > Thiodan > isodrin > endrin > Sevin > heptachlor > aldrin and dieldrin > DDT > chlordane;
at LD90: Thiodan > endrin > lindane > isodrin > Sevin > aldrin > heptachlor > dieldrin > DDT > chlordane.

All insecticides showed greater toxicity to the males than to the females except Sevin, which was more toxic to females (see Table 3). In this table, mortality listed for each day represents the cumulative kill from all concentration levels of the toxicants. The number of beetles killed during the first 2 days reflects the toxicity of the higher concentrations.

Toxicities of Residue.—The mortality resulting from a 5-minute exposure of the beetles to the sprayed blocks kept in the laboratory during the 13-week period is shown in figure 2. In contrast to the gradual decline in residual toxicity of endrin, Thiodan, and to a lesser degree isodrin, a rapid decrease is shown by lindane, aldrin, heptachlor, and chlordane during the first two weeks (fig. 2). The most gradual decline, however, was exhibited by DDT, which at the end of 13 weeks still showed about one-third of its original toxicity.

DISCUSSION.—When the initial toxicities of the residual deposits of the test materials are compared with their potencies as sprays, nearly the same order of relative toxicities is obtained. In the later residue tests, however, this is not true. Differing vapor pressures are probably the chief reason. For example, lindane, highly effective as a residue at first, is surpassed by DDT, dieldrin, and Sevin within 2 weeks.

Under the conditions of the residue tests, the usual environmental factors affecting toxicants in the field (sunlight, rainfall, high temperatures, and other forms of weathering) were either eliminated or held constant. The results must be interpreted with this fact in mind, since each of these conditions may have a different effect on each of the toxicants.

An interesting aspect of the comparison of the two types of screening tests used is that the Douglas-fir beetle appears to be much more susceptible to poisons in contact through the tarsi than through the body surface. From analyses of DDT-treated beetles as well as from the preliminary tests with a topical application method, it was noted that a toxic dose applied topically or as a spray is about 3 to 5 micrograms per beetle. It is quite unlikely that a beetle crawling over a treated surface for 5 minutes would pick up this much material, and yet appreciable kills were obtained.

It was noted that when the treated Firtex blocks were exposed to outdoor conditions for 2 weeks, during which 0.25 inch of rain occurred, none of the test materials showed appreciable toxicities when the usual exposure tests were made. This is thought to be largely caused by the leaching effect of the rain, which carried the wettable powder deposit beneath the surface of the test blocks and made it unavailable to the test insects. Therefore, the Firtex blocks are probably unsuitable for studying the

Table 2.—Relative toxicity of test materials to the Douglas-fir beetle.

INSECTICIDE	LD50 MG./100 ML.	LD90 MG./100 ML.	RELATIVE TOXICITY AT LD50	SLOPE RATIO
Lindane	22.1 (17.9– 27.2)[a]	122	23.5 (17.7–31.3)	1.0 (0.6–1.6)
Thiodan	25.0 (21.4– 29.2)	62	20.8 (16.2–26.6)	1.9 (1.3–2.8)[b]
Isodrin	30.5 (22.9– 40.6)	130	17.0 (12.0–24.2)	1.2 (0.7–2.2)
Endrin	42.0 (24.8– 81.0)	90	12.4 (7.1–21.7)	2.0 (1.0–4.0)[b]
Sevin	47.5 (19.8– 114.)	135	10.9 (4.4–26.9)	1.66[c]
Heptachlor	112 (78.3– 160.2)	552	4.6 (3.1– 7.0)	1.1 (0.6–2.0)
Aldrin	116 (60.7– 221.6)	350	4.5 (2.3– 8.8)	1.6 (0.7–3.3)
Dieldrin	116 (82.9– 162.4)	760	4.5 (3.0– 6.6)	0.87 (0.4–1.7)
DDT	520 (451 – 634)	2850	1.0 (standard)	1.0 (standard)
Chlordane	910 (684 –1210)	6600	0.6 (0.4– 0.8)	0.8 (0.4–1.7)

[a] Fiducial limits for 95% probability.
[b] Experimental error is small enough so that slopes may be considered not parallel.
[c] Fiducial limits for slope ratio are too large to add anything to the analysis.

Table 3.—Sex differences in the susceptibility of the Douglas-fir beetle to the test materials.

Insecticide	Cumulative Per Cent Killed								Number of Test Beetles	
	1st Day		2nd Day		3rd Day		4th Day			
	♂	♀	♂	♀	♂	♀	♂	♀	♂	♀
Aldrin	24	5	61	31	81	65	94	80	100	125
Chlordane	9	3	31	19	62	41	85	66	127	143
Dieldrin	22	9	69	38	86	66	96	89	123	157
DDT	13	7	52	32	81	64	96	77	183	177
Endrin	20	5	69	35	86	69	99	89	106	119
Heptachlor	13	7	57	31	91	77	99	91	141	144
Isodrin	14	3	54	22	76	55	89	84	114	141
Lindane	17	6	56	33	77	56	88	70	215	205
Sevin	28	18	58	64	62	74	71	78	127	158
Thiodan	17	5	63	36	85	68	99	88	123	147

effect of outdoor conditions. This viewpoint is supported by a field test (Allen & Rudinsky 1959) in which lindane, Thiodan, and Sevin gave good protection to Douglas-fir logs for at least 8 weeks after treatment. On a bark surface some leaching or penetration into the bark is probably an advantage in the control of bark and wood-boring insects.

The tests described offer convenient and rapid methods of screening potential toxicants for use against insect pests of forests. Toxicants that are promising in such studies may be considered good prospects for field tests.

References Cited

Allen, D. G., and J. A. Rudinsky. 1959. Effectiveness of Thiodan, Sevin, and lindane on insects attacking freshly cut Douglas-fir logs. Jour. Econ. Ent. 52(3): 482–4.

Bedard, W. D. 1950. The Douglas-fir beetle. U. S. Dept. Agric. Circ. **817,** Washington, D. C.

Dorman, S. C. and W. E. Hall. 1953. An improved spray tunnel method for laboratory tests. Jour. Econ. Ent. **46**(1): 151–3.

Litchfield, J. T., Jr., and F. Wilcoxon. 1949. A simplified method of evaluating dose-effect experiments. Jour. Pharmacol. and Exptl. Therapeutics, **95:** 99–113.

Moore, A. D. 1957. The relative toxicity of DDT, toxaphene, lindane and isodrin to *Dendroctonus brevicomis* Lec. and *Ips confusus* (Lec.). Jour. Econ. Ent. **50**(5): 548–50.

Vite, J. P., and J. A. Rudinsky. 1957. Contribution toward a study of Douglas fir beetle development. Forest Sci. **3:** 156–67.

Effects of Ronnel on Control of Cattle Grubs and Weight Gains of Beef Cattle[1]

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Abstract

Ronnel (formerly designated Dow ET-57, Korlan, or Trolene) was administered orally to calves for the control of *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.). The rates of administration were 100 to 110 mg./kg. of body weight in boluses and 92 to 99 mg./kg. in drenches prepared from an emulsifiable concentrate and wettable powder. Thirty-six animals that received the boluses about 3 weeks before grubs began encysting had an average of 0.5 grub. Untreated animals averaged 8.6. The drenches were given after the calves had an average of 3 encysted grubs. The emulsion, administered to 12 animals, failed to kill these grubs, and an additional 3 per animal encysted later. The suspension, given to 12 animals, was effective in killing those encysted, and less than one additional grub per animal encysted. The untreated animals averaged 20. The animals treated with the boluses were concurrently used in a fattening experiment. From January to April, when the grubs were most numerous in the backs of the animals, they gained 24 pounds more than those untreated. This difference was not statistically significant. The gains in weight of calves that were drenched and maintained on a high-silage ration did not vary significantly from those of the untreated animals.

Numerous chlorinated hydrocarbon and organic phosphorus insecticides have been administered to cattle and found to possess systemic action in controlling cattle grubs, *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.) (McGregor *et al.* 1954, 1955). Roth & Eddy (1957) and also McGregor & Bushland (1957) found that oral administration of ronnel was effective against both species present in the backs of cattle as well as against the encystment of new ones. Field tests reported by Jones & Brundrett (1957) and Adkins (1957) showed it was effective when given orally before the grubs encysted.

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In 1956–57 experiments were conducted at Lincoln, Nebraska, to determine the effects of ronnel in controlling cattle grubs and thereby inducing greater weight gains in beef cattle.

PROCEDURE.—Weanling calves that were being utilized for feeding experiments by the Nebraska Agricultural Experiment Station were used in these studies. They were native Hereford cattle weighing approximately 500 pounds at the beginning of the tests.

Three groups of calves were used. Group 1, consisting of 80 animals, were fed a standard Corn Belt fattening ration consisting of ground shelled corn, soybean oil meal, and chopped alfalfa hay. Various hormone or hormone-like substances were added to the ration or administered as implants. The rations and treatments have been reported by Matsushima *et al.* (1957). The calves were divided into 8 pens of 10 each. Ronnel in boluses was administered with a balling gun to five calves in each lot, and the remaining calves served as controls. The 10-gram boluses were divided into four parts so that the dose ranged from 100 to 110 mg. of active ingredient per kilogram of body weight. Treatment was made on December 4, about 2 to 3 weeks before grubs began appearing in the backs of the untreated animals.

Group 2, consisting of 24 calves, was fed a ration composed largely of Atlas Sorgo silage plus various supplements. The rations and management procedures have been reported by Dowe *et al.* (1957). There were four pens of six animals each. Three calves in each pen were treated on December 18 with a drench prepared by diluting a 50% emulsifiable concentrate of ronnel with tap water to make a 10% emulsion. This preparation was administered with a bottle at the rate of 92 to 99 mg. of active ingredient per kilogram of body weight. The remaining three calves in each pen were designated as controls.

Group 3 consisted of the same number of calves as group 2 and received the same rations. They were also divided and treated on the same date and in the same manner except that the drench was a suspension prepared from a 25% wettable powder of ronnel. Grubs had begun to encyst in the backs of the animals in both groups when the treatment was made.

The procedure followed in the conduct of the feeding experiments included the weighing of the animals at approximately 4-week intervals. The data were used to compare the gains of the insecticide-treated animals with the gains of those not treated.

CONTROL OF GRUBS.—The cattle were examined for grubs and weighed at 28-day intervals from December through May. The total number of grubs in each treated animal was obtained by indicating the position of each grub on a chart. Many of the untreated animals, however, were so heavily infested that cumulative counts were inaccurate and difficult to make. New grubs often appeared very near the locations of previously emerged grubs. Therefore, the grub counts reported for these animals are the maximum numbers found at one time.

A total of 17 grubs was found in the 36 bolus-treated animals that remained in this group until the test was completed. During December, January, February, and March, respectively, the numbers of grubs that encysted were 2, 8, 6, and 1. The grubs were found in 12 of these animals, an average of 0.5 grub per animal. Of the 39 untreated animals that completed the test, 38 were infested with one or more grubs each. The infestation ranged from 1 to 38 grubs, an average of 8.6 per animal.

On the date that the emulsion was administered to the animals in group 2, 42 encysted grubs were present. Thirty-eight survived the treatment, and an additional 38 appeared during January, February, and March. The average infestation in the 12 treated animals was 6.3 grubs per animal. All the 12 untreated animals were infested with an average of 18.3 grubs each.

The 12 animals in group 3 had 38 grubs encysted in their backs on the date of treatment. These grubs were dead and no new ones had encysted 24 days later. However, a total of seven grubs did migrate to the backs of four animals and completed their development during February and March. The 12 untreated animals had an average of 21.2 grubs each.

The failure of the emulsion to kill more than 10% of the encysted grubs and the complete kill of those in the suspension-treated animals indicate that the emulsion was an inferior preparation. The emulsifiable concentrate tended to flocculate at low temperatures. This condition was also noted in the drench. Although warm water was used to make the drench, considerable cooling occurred while each dose was measured and poured into the bottle for administration. The temperature at that time was 34° to 36° F.

Both species of cattle grubs were present in these animals. A few grubs that were extracted from the untreated animals at each check period indicated that between 55 and 60% of the population was *H. lineatum*. The last grubs to encyst did not leave the backs until May.

WEIGHT STUDIES.—The periodic weight gains in the animals given the boluses are shown in table 1. Between the latter part of December and the first part of April, when the grubs were most abundant, the treated animals gained 24 pounds more per head than the untreated. However, during the early and latter parts of the 221-day feeding period the untreated animals outgained those that were treated. These differences were not significant.

The periodic weight gains of the animals treated with the drenches are presented in table 2. The animals that were treated with the emulsion gained an average of 6 pounds less than the untreated animals. These lower gains plus the poor control of grubs indicate that this treatment was the least effective of the three used.

The slight increase in rate of gain by the animals

Table 1.—Effect of treatment with ronnel boluses on periodic weight gains of beef cattle. (Pounds per animal.)

PERIOD (1957)	UNTREATED	TREATED
Nov. 6 (1956) to Dec. 4	72	72
Dec. 4 to 26	36	34
Dec. 26 to Jan. 29	84	90
Jan. 29 to Feb. 26	71	80
Feb. 26 to Mar. 26	56	65
Mar. 26 to Apr. 23	62	56
Apr. 23 to May 21	58	56
May 21 to June 14	59	56
Total	498	509

Table 2.—Periodic weight gains (pounds per animal) of cattle treated with emulsions and suspensions of ronnel for grub control.

Period (1957)	Emulsion Treatment—Group 2		Suspension Treatment—Group 3	
	Untreated	Treated	Untreated	Treated
Dec. 14 (1956) to Jan. 8	60	60	54	58
Jan. 8 to 19	7	9	9	7
Jan. 19 to Feb. 15	55	54	54	56
Feb. 15 to Mar. 15	35	33	29	34
Mar. 15 to Apr. 23	54	49	56	52
Total	211	205	202	207

treated with the suspension over that of those untreated tended to be the greatest when the grubs were most abundant in the backs.

Regardless of the form of ronnel used in these tests, there was a slight depression of appetite during the first 24 to 36 hours. This observation was reported by the herdsman. He noted that less feed was consumed and that the treated animals stayed away from the feed bunks. Aside from the loss of appetite, there were no visible symptoms of toxicity.

References Cited

Adkins, Theodore R., Jr. 1957. Field evaluation of Dow ET-57 as a systemic insecticide for the control of the common cattle grub in Alabama. Jour. Econ. Ent. **50**(4): 474–6.

Dowe, T. W., J. Matsushima, V. H. Arthaud, and P. L. Jillson. 1957. Atlas sorgo silage for wintering steer calves. Nebraska Cattle Progress Rept. 246, 45th Annual Feeders Day. Nebr. Agric. Expt. Sta.

Jones, Robert Henry, and H. M. Brundrett. 1957. Ranch tests against cattle grubs with the systemic insecticide Dow ET-57. Agric. Chemicals **12**(7): 45, 95–96.

Matsushima, J., T. W. Dowe, V. H. Arthaud, and P. L. Jillson. 1957. Hormones and hormone-like stubstances for fattening calves. Nebraska Cattle Progress Rept. 249, 45th Annual Feeders Day. Neb. Agric. Expt. Sta.

McGregor, W. S., R. D. Radeleff, and R. C. Bushland. 1954. Some phosphorus compounds as insecticides against cattle grubs. Jour. Econ. Ent. **47**(3): 465–7.

McGregor, W. S., R. D. Radeleff, H. V. Claborn, and R. C. Bushland. 1955. Dieldrin, aldrin, and lindane as systemic insecticides against livestock pests. Agric. Chemicals **10**(1): 34–36, 123.

McGregor, W. S., and R. C. Bushland. 1957. Tests with Dow ET-57 against two species of cattle grubs. Jour. Econ. Ent. **50**(3): 246–9.

Roth, A. R., and G. W. Eddy. 1957. Tests with Dow ET-57 against cattle grubs in Oregon. Jour. Econ. Ent. **50**(3): 244–6.

An Altitude Biting Study of *Culex tritaeniorhynchus* (Giles) and Other Associated Mosquitoes in Japan[1]

Milton B. Flemings[2]

Abstract

At Sagiyama, Japan, *Culex tritaeniorhynchus* (Giles), the vector of Japanese encephalitis virus in the Fart East, was found to bite black crowned night herons (BCNH) (a species known to host the virus of Japanese encephalitis) at all levels up to 50 feet. The biting rate was overwhelmingly higher at ground level with a decreasing biting rate up to 50 feet.

Culex pipiens (L.) and *C. bitaeniorhynchus* (Giles) biting rates suggested the same trend as that of *C. tritaeniorhynchus*. *Armigeres subalbatus* was collected from the ground level only. Other associated mosquito species attracted to BCNH-baited traps were too few to be considered in this study.

The 1956 Professional Report of the 406th Medical General Laboratory, APO 343, San Francisco, California, contains information pertaining to the relationship of the high biting rate of *C. tritaeniorhynchus* at ground level to susceptible nestliing birds that fell to the ground before the age of flight.

For trapping live mosquitoes at different altitude levels, aerial traps modified after that described by Magoon (1935) and Bates (1944) were used.

The mosquito *Culex tritaeniorhynchus* (Giles) is considered the principal vector of Japanese encephalitis in Japan. As a supplement to an overall study of the natural history of this disease in Japan (anonymous 1952–55, 1956), an altitude biting study of its vector and other associated mosquitoes was conducted by the U. S. Army's 207th Medical Detachment (PMS). The vector and virus host relationship rendered it advisable to know the biting habits of mosquitoes, especially *C. tritaeniorhynchus*, at various altitudes where birds would nest their young susceptibles.

Material and Procedure.—For trapping live mosquitoes at different levels, aerial cage traps modified after that described by Magoon (1935) and Bates (1944) were used. Traps were baited with black crowned night herons (BCNH), of the Family Ardeidae. Modification of the traps included external dimensions 36×36×24 inches, convenient size doors 6×12 inches, and pulleys which permitted adjustment of the traps to different levels (fig. 1).

The study was conducted from July 4 to October 3, 1956, at Sagiyama, Japan, which was an ideal location, as the area was an annual seasonal nesting haven for three

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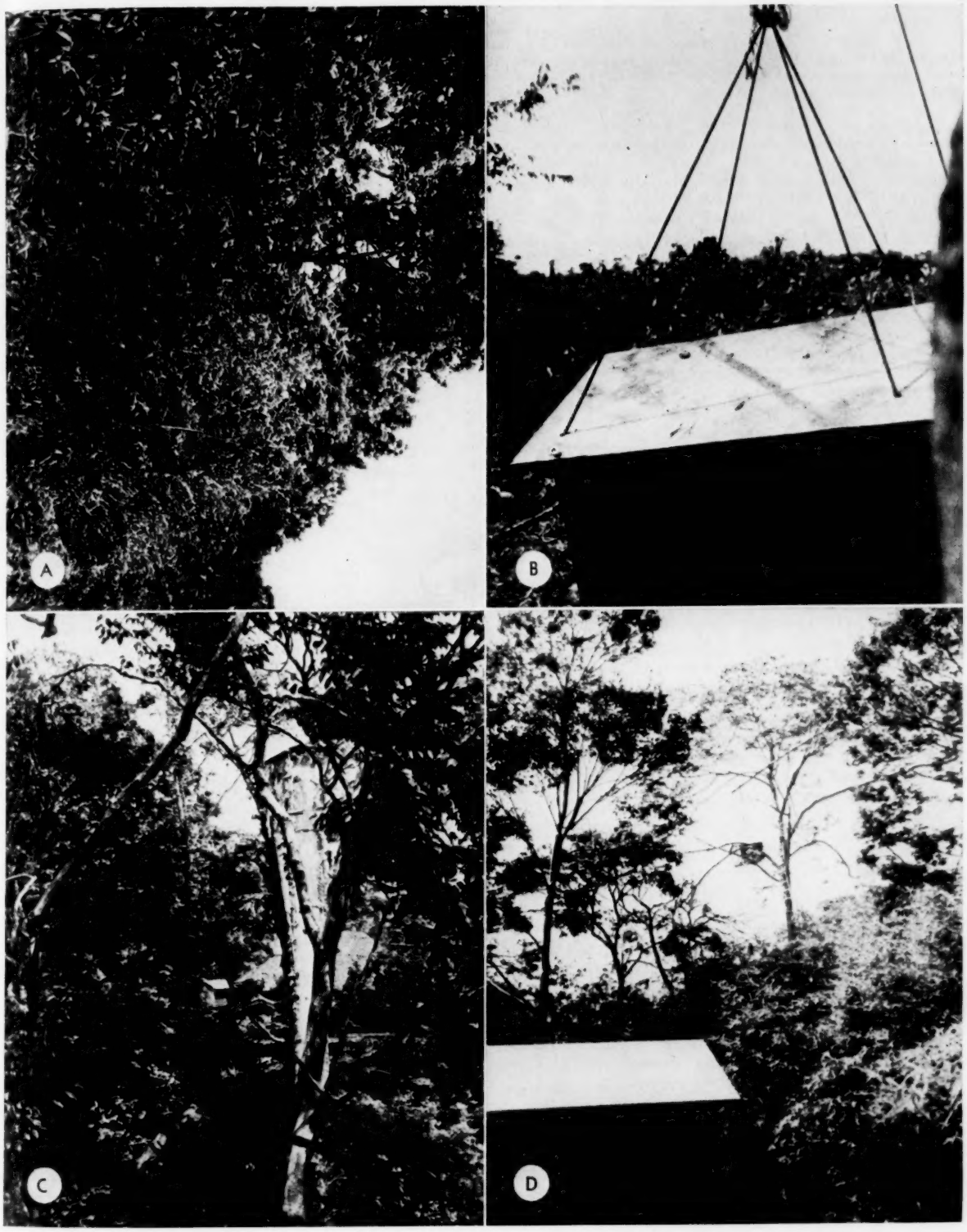

FIG. 1.—Bird-baited aerial cages used for trapping live mosquitoes at different altitude levels. Subfigures A, B, C, and D show the cages at different levels.

Table 1.—Average number of mosquitoes per collection[a] at different altitude levels, by species and total.

Months	Trap Altitudes	*Aedes albopictus*	*Aedes vexans*	*Armigeres subalbatus*	*Culex Bitaeni orhynchus*	*Culex orientalis*	*Culex pipiens*	*Culex Tritaeni orhynchus*	*Culex vorex*	Total
July	Ground	0	0	5.2	6.2	0	60.4	44.0	0	115.8
	20–29′	0	0	0	0.4	0	6.7	1.0	0	8.2
	30–39′	0	0	0	0.8	0.1	6.6	2.1	0	9.5
	40–50′	.03	.03	0	0.5	0	2.9	0.5	0	3.9
Aug.	Ground	0	0	0.5	0.5	0	4.0	3.5	0	8.5
	10–19′[b]	0	0	0	0	0	2.3	0.8	0	3.0
	20–29′	0	0	0	0.6	0	1.4	0.3	0	2.4
	30–39′	0.1	0	0	0.6	0	1.4	0.1	0	1.9
	40–50′	0	0	0	0.2	0	0.2	0	0.1	0.5
Sept.	Ground	0	0	0	0.1	0	2.1	0	0	2.2
	10–19′	0	0	0	0.1	0	1.0	0.1	0	1.2
	20–29′	0	0	0	0.1	0	0.4	0	0	0.5
	30–39′	0	0	0	0	0	0	0	0	0
	40–50′	0	0	0	0	0	0	0	0	0

[a] Three collections per week.
[b] 10–19 ft. traps began operating on August 24, 1956.

species of Ardeids: BCNH, plumed egrets, and great egrets (anonymous 1952–55). Ardeids nested freely in trees (the common pine tree, *Pinus densiflora;* liveoak, *Quercus acuta; Zelkova serrata;* and bamboo, *Pseudossa japonica*) at levels from 10 to approximately 50 feet which influenced the placement of aerial traps. BCNH were chosen for this study because of their established biting preference by *C. tritaeniorhynchus* and their established record as host for the virus of Japanese encephalitis (anonymous 1952–55).

BCNH baited traps were operated at ground- to 50-feet levels 24 hours each day with two young birds per trap as follows:

Trap Altitudes	*No. of Weeks Operated*	*No. of Collections per Week*	*No. of Traps Used*
40–50 ft.	12	3	2
30–39 ft.	12	3	2
20–29 ft.	12	3	2
10–19 ft.	6	3	2
Ground	12	3	5

RESULTS AND DISCUSSION.—Table 1 presents the average number of each mosquito species recovered per collection from four altitude levels and the ground level (three collections per week). It suggests that *C. tritaeniorhynchus* will feed on BCNH at all levels as high as 50 feet, and that the biting rate was overwhelmingly higher at ground level. *C. pipiens* (L.) and *C. bitaeniorhynchus* (Giles) also will bite at each level, the highest biting rate being at ground level. *Armigeres subalbatus* (Coq.) was collected from the ground level only. Other species of mosquitoes listed in table 1 were too few to be considered.

Inspection of the data in table 1 suggests that above the ground level, the biting rate of *C. tritaeniorhynchus* and *C. pipiens* decreased with increasing height up to 50 feet.

Numerous young heron and egret birds were observed on the ground, having fallen from their nests before they were capable of flight. The relationship between these nestlings and the high biting rate of *C. tritaeniorhynchus* at ground level is included in the 1956 Professional Report of the 406th Medical General Laboratory, Virus and Rickettsial Section.

REFERENCES CITED

Anonymous. 1952–55. Professional Reports. 406th Medical General Laboratory, United States Army, Far East: Virus and Rickettsial Sections.

Anonymous. 1956. Professional Report. 406th Medical General Laboratory, United States Army, APO 343, San Francisco, California: Virus and Rickettsial Section.

Bates, M. 1944. Notes on the construction and use of stable traps for mosquito studies. Jour. Nat. Malaria Soc. **3**: 135–45.

Magoon, E. H. 1935. A portable stable trap for capturing mosquitoes. Bull. Ent. Res. **26**(3): 363–9.

Control of the Apple Aphid and the Rosy Apple Aphid with New Spray Chemicals[1]

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ABSTRACT

Orchard trials with new spray chemicals for the control of the rosy apple aphid (*Anuraphis roseus* Baker) and the apple aphid (*Aphis pomi* De Geer) were conducted on Yellow Newtown and Red Delicious apples during 1957 and 1958. Delayed dormant sprays against eggs of the rosy apple aphid demonstrated that ethion-oil, Phostex®, (a mixture of bis (dialkyloxyphosphinothioyl) disulfides)-oil, and Trithion® (*S*-(*p*-chlorophenylthio)methyl *O,O*-diethyl phosphorodithioate)-oil gave control equal to the standard oil-dinitro sprays, and did not injure the cover crop. Foliage treatments for the rosy apple aphid in 1957 and 1958 indicated that systemic compounds, demeton, Thimet® (*O,O*-diethyl *S*-(ethylthio) methyl phosphorodithioate), dimethoate Am. Cyanamid 18706® (*O,O*-dimethyl *S*(N-ethyl carbamoylmethyl) phosphorodithioate), and Di-syston® (*O,O*-diethyl *S*-2-(ethylthio)-ethyl phosphorodithioate) would provide good control. Diazinon® (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothiate) was the only nonsystemic material to provide control of the rosy apple aphid. Guthion® (*O,O*-dimethyl *S*-(4-oxo-3*H*-1,2,3-benzotriazine-3-methyl) phosphorodithioate), Sevin® (N-methyl-1-naththyl carbamate), Rohm-Haas C-140® (dimethyl carbamate of 2-dimethylaminomethylphenol hydrochloride), ethion, and Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) were not effective.

Summer treatments for control of apple aphid were applied during the 1957 and 1958 seasons. Apple aphid does not become a problem until June, and repeated reinfestation makes control difficult. The systemic compounds Thimet, Di-syston, Am. Cyanamid 18706, and dimethoate provided the best control. Nonsystemic compounds, although reducing populations following the application, did not prevent reinfestation and rapid buildup.

The apple aphid, *Aphis pomi* De Geer, and the rosy apple aphid, *Anuraphis roseus* Baker, are both common pests in the apple districts of California. The apple aphid is the more serious, as infestations are continuous during the summer months. The damage caused is twofold: the new growth is attacked and stunted, and honeydew produced by the aphids drips to the foliage and fruit. The rosy apple aphid is potentially the more damaging, as the attack of the aphid stunts and deforms the fruit in addition to curling the leaves. It is usually held under control by dormant sprays however, and heavy infestations are rare in well cared for orchards.

During the 1957 and 1958 seasons, field trials were conducted on the control of both aphid species. In each season the same plots were used for the rosy apple aphid and the apple aphid, but each species will be discussed separately.

ROSY APPLE APHID 1957–1958.—The standard treatment for winter control of aphid eggs in California is dormant oil with the addition of a dinitro compound. Chapman & Avens (1948) have demonstrated the effectiveness of dinitro compounds against aphid eggs, and control with the compounds in California has been satisfactory. Combinations of oil and dinitro are effective weed killers however, and severe injury has been caused to winter cover crops following dormant sprays.

Oil-phosphate combinations have shown promise as winter treatments for scale insects, and it was decided to try some of these combinations for aphid-egg control. If the materials were effective, it would eliminate the hazard of cover-crop damage.

A plot was established during the 1957 season in a mature yellow Newtown apple orchard near Watsonville, California, in order to test three of these combinations. Each treatment was applied to a 6×16 block of trees, with a 6×6 unsprayed section between each treated block. Materials used were ethion-oil miscible, Phostex® (a mixture of bis (dialkyloxyphosphinothioyl) disulfides)-oil miscible, and Trithion® (*S*-(*p*-chlorophenylthio) methyl *O,O*-diethyl phosphorodithioate) plus oil. Applications were made on March 21, at the delayed dormant period, using blower-sprayer equipment. The applied gallonage averaged 400 gallons per acre.

Control of the rosy apple aphid was evaluated in May by counting the number of infested shoots on 16 trees in the center of each treated plot. The center six trees in each unsprayed block were examined in the same manner.

Winter eggs of European red mite, *Panonychus ulmi* (Koch), were numerous in this orchard, therefore the effect of the treatments on mite eggs was evaluated by taking foliage mite counts during May and June. The counts were made by picking 100 leaves at random from the center trees on each plot. The leaves were run through a mite brushing machine as described by Morgan *et al.* (1955), and the mites were then counted under a binocular microscope.

The materials used, dosages, the rosy apple aphid and the European red mite counts are summarized in table 1. The results showed that the oil-phosphate combinations were effective in controlling the winter eggs of the rosy apple aphid. The few infested shoots in the ethion-oil plot were at the top of an exceptionally high tree, and probably represented an area missed by the spray. Trithion-oil and ethion-oil were both effective against the winter eggs of European red mite, but Phostex-oil did not provide adequate control.

A block of trees had been set aside for experimental work with woolly apple aphid, *Eriosoma lanigerum* (Hausm.), during the spring of 1957. Since the trees did not receive a dormant spray, a heavy infestation of the rosy apple aphid developed on these trees in late April. The first treatments for control of the woolly apple aphid were applied on May 6, and the effects of the various compounds on the rosy apple aphid were determined. The plots were located in a young Yellow Newtown apple or-

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Table 1.—Control of the rosy apple aphid and the European red mite with delayed dormant sprays—1957.

Materials	Dosage per Acre[a]	Average No. Shoots per Tree Infested with Rosy Apple Aphid	Average No. European Red Mites per Leaf		
			May 10	June 6	June 21
10% Phostex-oil miscible	3.6 gal.	0.0	0.6	6.4	12.6
5% ethion-oil miscible	3.6 gal.	0.7	0.2	0.2	0.5
48% Trithion+dormant oil	3.6 pt.+7.2 gal.	0.0	0.1	0.2	0.7
Untreated		7.5	1.3	6.7	13.4

[a] All treatments were applied on March 21.

chard, and each treatment was applied to single trees with eight replications. Materials were applied with a conventional high pressure spray rig and hand guns. The gallonage used averaged 350 gallons per acre.

The plots were evaluated 4 and 10 days after treatment by selecting 25 curled leaves per treatment, and examining them for living and dead aphids. The materials used, dosages, and the percentage of mortality are summarized in table 2.

The results showed that the systemic compounds Thimet® (*O,O*-diethyl *S*-(ethylthio) methyl phosphorodithioate) and demeton gave excellent control. Of the nonsystemic compounds, Diazinon® (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothiate) was effective, but Guthion® (*O,O*-dimethyl *S*-(4-oxo-3*H*-1,2,3-benzotriazine-3-methyl) phosphorodithioate), ethion, and Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) did not provide satisfactory control. By the end of May the new growth on trees in the plots treated with the latter three materials was heavily infested.

In the 1958 season, studies were conducted on both the rosy apple aphid and the apple aphid. The test block of trees were of the Red Delicious variety, and these were left untreated during the dormant season. By early May, curled leaves were abundant, denoting the presence of the rosy apple aphid. The compounds selected for the 1958 field trials were applied to the trees on May 6, using the same spray equipment as previously described. Each treatment was applied to a block of nine trees with three replications in a randomized block design. The trees were very small, and approximately 2 gallons of spray were applied to each tree.

One week after application, the plots were evaluated by collecting 25 curled leaves from each treatment and examining them for living and dead aphids. Two weeks after application, a different method of evaluation was used. By this time, new growth had unfolded and was infested in some plots and not in others. Therefore, counts were made by examining 20 twigs per replicate that showed evidence of attack by the rosy apple aphid. The number of shoots with the new growth infested were recorded. The materials used, dosages, and percentage of aphid control and of new shoots infested are summarized in table 3.

The systemic compounds used in these trials, Di-syston® (*O,O*-diethyl *S*-2-(ethylthio)-ethyl phosphorodithioate), Am. Cyanamid 18706® (*O,O*-dimethyl *S*(N-ethyl carbamoylmethyl) posphorodithioate), and dimethoate gave excellent control. Sevin®(N-methyl-1-naththyl carbamate) was partially effective, but the surviving aphids were able to reestablish active colonies on new growth within a month's time. Guthion and Rohm-Haas C-140® (dimethyl carbamate of 2-dimethylaminomethylphenol hydrochloride) did not give satisfactory control.

APPLE APHID 1957–1958.—Under California conditions, apple aphid becomes a problem in early summer. It has been pointed out by Cutright (1953) that winter sprays are not sufficient to prevent summer buildup. The problem of reinfestation makes control difficult, and Glass & Chapman (1955) have shown that a systemic compound is necessary to avoid repeated applications.

During the 1957 season, as has been previously mentioned, plots were established for the control of woolly apple aphid. Apple aphid become noticeable on the trees by late June. Since a treatment was applied for woolly apple aphid control on July 11, it was possible to evaluate the test compounds against the apple aphid. The method of application was the same as described under the sec-

Table 2.—Control of the rosy apple aphid with foliage treatments, 1957.

Material	Dosage per 100 Gallons[a]	Per Cent Mortality	
		May 10	May 16
Demeton, E.C.	1 pt. 21%	100	100
Thimet, E.C.	1 qt. 48%	100	100
Thimet, E.C.	1 pt. 48%	100	100
Diazinon, W.P.	1 lb. 25%	99.2	98.8
Guthion, E.C.	1.5 pt. 18%	40.3	73.0
Ethion, W.P.	1 lb. 25%	28.1	59.0
Thiodan, W.P.	2 lb. 25%	34.5	68.2

[a] Sprays applied on May 6.

Table 3.—Control of the rosy apple aphid with foliage treatments, 1958.

Materials	Dosage per 100 Gallons[a]	Per Cent	
		Control of Aphids May 13	New Shoots Infested. May 27
Guthion, W.P.	3 lb. 12½%	2.3	80.0
Am. Cyanamid 18706, E.C.	1 qt. 25%	100	0
Sevin, W.P.	1½ lbs. 50%	81.4	16.6
Di-syston, E.C.	1 pt. 18%	100	0
Dimethoate, E.C.	1 pt. 50%	100	0
Rohm-Haas C-140, E.C.	1 pt. 65%	48.7	50.0
Untreated		0	93.3

[a] Materials applied on May 6.

tion on the rosy apple aphid. The plots were evaluated in two ways, one by aphid counts after application, and the other by examining the fruit for the presence of honeydew at harvest. Aphid counts were made by selecting the third leaf down from the terminal of an infested shoot, and 25 leaves were collected per treatment. It was recognized that the aphids prefer the actively growing shoots, and that reinfestation takes place on the terminal leaves. The third leaf from the tip was taken in order to sample in an area which had received the spray treatment and was succulent enough to be suitable for reinfestation. The leaves were placed in an aphid sampling can as described by Gray & Schuh (1941), and the aphids were then counted.

At harvest, 100 apples were picked at random from each plot, and rated on the amount of honeydew and black smut fungus that was present on the apples. Those apples with more than 10% of the surface covered with honeydew were considered as damaged. The materials used, dosages, aphid counts and percentage of fruit damage are summarized in table 4.

Thimet, at the quart and pint dosages, Guthion, and Thiodan gave good control of the apple aphid. Diazinon and ethion were less effective in these trails. Under the 1957 seasonal conditions, the apple aphid populations declined rapidly after August, and it was not possible to determine how the compounds would perform under conditions of rapid reinfestation. It should be pointed out that the previous treatment history on the plots played a role in the final results. Sprays had been timed according to the woolly apple aphid populations, and theT himet and Diazinon plots had received only one spray in May prior to the July 11 treatment. The trees in the plots treated with Guthion, ethion or Thiodan had received two prior treatments, one on May 6 and the other on June 10.

In 1958, a young Red Delicous apple orchard was chosen for the apple aphid trials, as it has been observed by many workers that the apple aphid prefers vigorously growing trees with tender new foliage. In order to determine when the apple aphid first appeared, aphid bait pans were used to trap alates flying into the orchard. The pans were painted yellow, filled with water, and suspended at a 5-foot height at the four sides of the orchard. The trees were checked for apple aphids shortly after bloom, and at frequent intervals thereafter. Rosy apple aphids were abundant, but no stem mothers of the apple aphid were seen. On May 20, the first apple aphids were picked up in the bait pans. These were alates and shortly thereafter, colonies were found on the new growth. By early June, infestations had increased to the point where it was necessary to apply the first treatments. The plot set up was the same as described under the discussion of the rosy apple aphid, and the same spray equipment was used. The first sprays were applied on June 2, and a second application was made on July 1,

Table 4.—Control of the apple aphid, 1957.

Materials	Dosage per 100 Gal.[a]	Aphids per 25 Leaves		Per Cent Apples Damaged by Honeydew
		July 25	August 1	
Thimet, E.C.	1 qt. 48%[b]	20	35	0
Thimet, E.C.	1 pt. 48%[b]	57	55	6.0
Diazinon, W.P.	1 lb. 25%[b]	150	125	19.0
Guthion, E.C.	1½ pt. 18%[c]	87	32	0
Ethion, W.P.	1 lb. 25%[c]	320	242	27.0
Thiodan, W.P.	2 lb. 25%[c]	117	30	0.
Untreated		715	370	58.0

[a] Materials applied on July 11.
[b] Previously treated on May 6.
[c] Previously treated on May 6 and June 10.

After treatment, aphid samples were taken at intervals throughout the season. The technique used was the same as employed in 1957, except that a 50-leaf sample was taken rather than one of 25. In some plots, populations were very high with a 50-leaf sample, especially in the untreated trees. When high numbers were present, the aphids collected from the sampling can were placed in a jar with a uniform amount of water, agitated, and an aliquot sample was withdrawn.

In addition to the aphid counts, the fruit from the test trees was examined for honeydew and black fungus at harvest. One hundred apples were examined from each replicate, and those with 10% or more of the surface covered with honeydew were recorded as damaged.

The material used, dosages, aphid counts, and percentage of fruit damage are summarized in table 5.

The systemic compounds Di-syston, Am. Cyanamid 18706, and dimethoate controlled the apple aphids so that no damage was caused to the fruit. Even though populations built up on these plots a month after the last application, the aphids were restricted to the new growth. On other plots, the aphids spread from the new growth to the rest of the shoots as populations increased.

Table 5. Control of the apple aphid, 1958.

Materials	Dosage per 100 Gallons[a]	Aphids per 50 Leaves							Per Cent Fruit Damaged by Honeydew
		June 12	June 19	July 11	July 22	Aug. 8	Aug. 19	Sept. 3	
Guthion, WP	2 lb. 25%	141	720	123	1050	3490	2820	450	11.0
Am. Cyanamid 18706, EC	1 qt. 25%	6	90	63	60	730	760	180	0
Sevin, WP	1½ lb. 50%	287	930	250	2070	3610	2230	200	10.4
Di-syston, EC	1 pt. 18%	10	20	24	130	750	1110	270	0
Dimethoate, EC	1 pt. 50%	7	50	26	144	860	870	110	0
Rohm-Haas C-140, EC	1 pt. 65%[b]	244	650	150	3090	3040	2780	480	18.0
Untreated		4040	5570	6430	2200	1200	1140	160	100.0

[a] Materials applied on June 2 and July 1.
[b] Dosage increased to 1 quart on July 1.

Guthion, Sevin, and Rohm-Haas C-140 reduced the aphids following treatment, but reinfestation and buildup from those not killed took place within a relatively short time. The aphid populations on some of these latter treatments were almost as heavy as the checks as the season progressed. The fruit counts, however, did not show honeydew damage approaching the severity of those from the check trees. Apparently a continuous infestation of the apple aphid is more damaging than a heavy infestation of short duration. The apple aphid populations declined in all plots in mid-August, and by early September only a few aphids were still present.

Rohm-Haas C-140 at the quart dosage caused severe burn spots on the Red Delicous variety. None of the other compounds showed any phytotoxic effect.

European red mites were present on the plots and counts were taken at biweekly intervals. Di-syston and dimethoate were the only materials that did not require the addition of a specific acaricide.

References Cited

Chapman, P. J., and A. W. Avens. 1948. The toxicology of 4, 6 Dinitro-o-cresol as an aphid ovicide. Jour. Econ. Ent. **41**(2): 190–8.

Cutright, C. R. 1953. Controlling *Anuraphis roseus* and *Aphis pomi*. Jour. Econ. Ent. **46**(2): 379–81.

Glass, E. H., and P. J. Chapman. 1955. Summer control of the apple aphid. Jour. Econ. Ent. **48**(6): 695–7.

Gray, K. W., and Joe Schuh. 1941. A method and contrivance for sampling pea aphid populations. Jour. Econ. Ent. **34**(3): 411–15.

Morgan, C. V. G., A. D. Chant, N. H. Anderson, and G. L. Ayre. 1955. Methods for estimating orchard mite populations, especially with the mite brushing machine. Canadian Ent. **87**(5): 189–99.

A Method of Testing Insect Traps and Attractants, and Its Application to Studies of *Hippelates pusio* and *Culex tarsalis*[1]

Richard P. Dow[2]

Abstract

A test developed by the author to compare baits attractive to the eye gnat (*Hippelates pusio* Loew) has also proved useful in investigations of *Culex tarsalis* Coq., both in studies of the avian hosts of this mosquito (previously reported) and in the evaluation of different traps. The basic feature is the slow rotation around a central point, at a fixed radius and in a horizontal plane, of identical traps containing different baits, or of different traps containing identical baits. The apparatus used for this purpose is called a rotary. The advantage of the method derives from its reduction of site differences. When, in accordance with a Latin-square design, each bait is tested in each trap in a multiple-period test, it is possible, through analysis of variance, to evaluate separately the effects of baits, traps, and periods of test. If one element (baits or traps) is found not to make a definite contribution to total variance, other designs become available. Similar apparatus and tests have been developed and used by other workers, the first of whom was apparently D. E. Eyles.

Use of rotary testing has shown that, upon exposure to air, liver bait for *H. pusio* becomes more attractive over a period of 1 or 2 days, that exposure to air does not increase its attractiveness to *Hippelates bishoppi* Sabrosky, that bait which putrefies under aerobic conditions is more attractive to *H. pusio* than bait matured anaerobically, and that the liver bait used in the writer's studies was more attractive to *H. pusio* than an egg bait originated by E. R. Tinkham. In tests of CO_2-baited traps for *C. tarsalis*, those of larger size were found more efficient, and no baffle was found superior to a round entrance at the apex of an inwardly directed cone of wire screening.

In the field testing of insect traps and attractants, differences in test locations are a troublesome source of variation. In critical comparisons, test sites must be given special consideration in the experimental design, and when they introduce too much variation to control by randomization or simple balance, their effects must be separable from those of other factors. An excellent analysis of the problem written by Williams (1951), and summarized in one remarkable paragraph in a later paper (Williams *et al.* 1955) includes the statement that "no two traps can be on the same spot at the same time." This epitomizes the importance of the place-to-place and time-to-time differences which plague the comparison of traps and attractants.

The technique discussed in this article involves two basic features. One is the horizontal rotation of the test items, carrousel-fashion, around a central point. This is accomplished by means of an apparatus called a rotary (Dow *et al.* 1957). Slow rotation of the baited traps effectively reduces or eliminates site differences.

The other basic feature of the rotary technique is the use of appropriate experimental designs. These are especially important if it is necessary to control variance from sources not under test (night-to-night differences, and differences among traps or baits).

The purpose of this article is: first, to describe and evaluate the testing of traps and attractants by means of a rotary, and second, to report on results of applying this technique to studies of *Hippelates pusio* Loew, the eye gnat, and *Culex tarsalis* Coq., a primary vector of western equine and St. Louis encephalitis (Hess & Holden 1958).

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[2] Dr. R. E. Serfling suggested the use of Latin-square designs at a critical stage in the writer's development of the rotary tests; Dr. Otis Emik proposed the designs with equalized sequences; and Dr. Myron J. Willis has provided guidance and assistance of various kinds for several years. The writer takes pleasure in acknowledging this help, also the information graciously supplied by Dr. Don E. Eyles.

ORIGIN OF THE METHOD.—In 1950, wooden traps baited with putrefied liver were used to measure the prevalence of *H. pusio* in nine communities in southwest Georgia. The standard bait was made of equal weights of ground pork liver and water, with an ounce of crystalline urea for each pound of liver. After 2 weeks at room temperature it was typically an olivaceous black slurry with a powerful odor. Occasionally the catches of the traps baited with this attractant seemed to bear little or no relationship to the numbers of eye gnats observed by the men in the field. At the time, these irregularities were thought to result from differences among the mixes of bait prepared weekly, or even among separate jars of the same mix. To produce a reliably uniform attractant appeared to require the development of a suitable testing technique.

Since there was strong evidence for place-to-place differences in trap success, it was advisable to locate the test traps within a few feet of each other. It was still necessary, however, to show that when each trap was baited with the same attractant, all would have an equal chance to attract gnats. In 30 trials of closely spaced, identically baited traps, the numbers of the *pusio* group caught in the four traps of each set differed so greatly from each other that it appeared desirable to operate all the traps at the same place at the same time. This logical impasse was essentially solved by placing the traps on a slowly revolving turntable.

APPARATUS.—Two types of rotary have been built and used: a gnat-trap rotary, essentially a low turntable (fig. 1), and a mosquito-trap rotary, which has a central support and radiating arms (fig. 2). It seems unnecessary to give detailed information about the construction of this apparatus because the essential functions may be obtained in a variety of ways. The gnat-trap rotary was originally powered by a 15 r. p. m. motor from an electric ice-cream freezer, later by a 78 r. p. m. electric phonograph motor. The drive mechanism used for the mosquito-trap rotaries is part of a U. S. Signal Corps Radio Set (SCR-547), and consists of a 1/70 hp. electric motor and a variable-speed reversible drive (KS-8717 Drive, Western Electric Co.[3]). The turntable of the gnat-trap rotary was 4 feet in diameter. It held the traps and also served as a giant pulley for the belt bringing power from the motor. In the mosquito-trap rotary, the turntable is essentially a pulley but can be used to support apparatus. No matter how the traps are rotated, the motion should be slow and steady, with minimum production of heat, noise, and odor. The speed of the traps should be adjustable, as in the mosquito-trap rotary, both by regulating the angular velocity and by changing the radius of the circle. Since there is no need for rapid rotation, a Cuttyhunk (linen) fishline, thoroughly waterproofed, makes an ideal belt. In the gnat-trap rotary, the motor was kept intentionally at some distance from the traps, but experience at night with the mosquito-trap rotary has shown that, because of stray animals, it is

[3] Mention of the manufacturer's name is for descriptive purposes only and does not constitute endorsement by the Public Health Service.

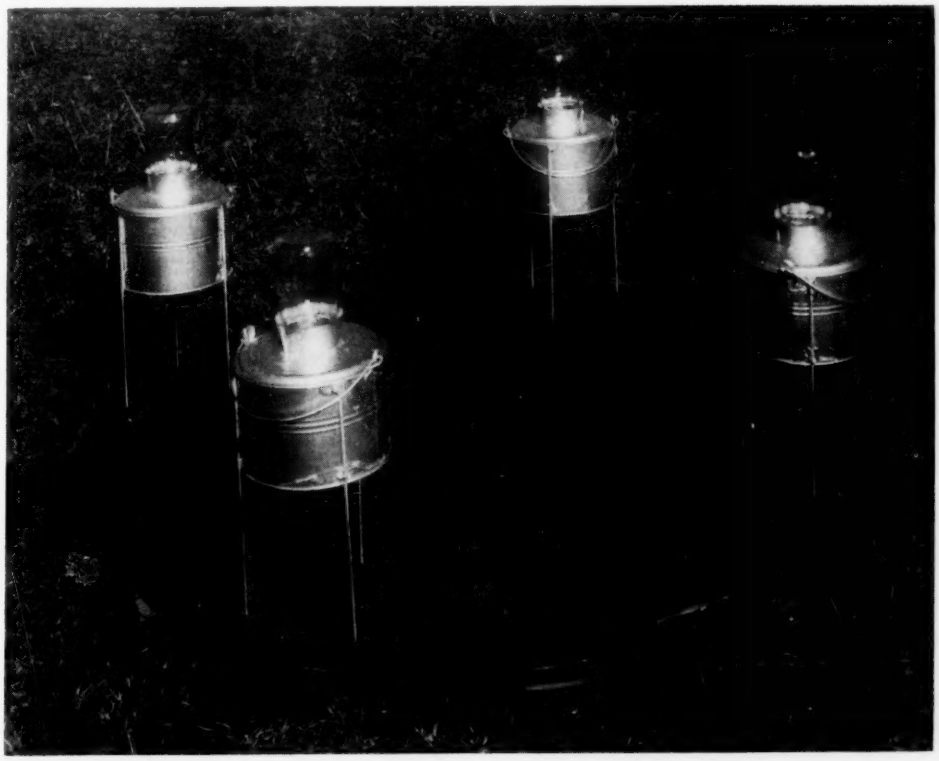

FIG. 1.—Gnat-trap rotary with metal gnat traps. The drive mechanism, mounted on a heavy block of wood, was placed about 10 feet away.

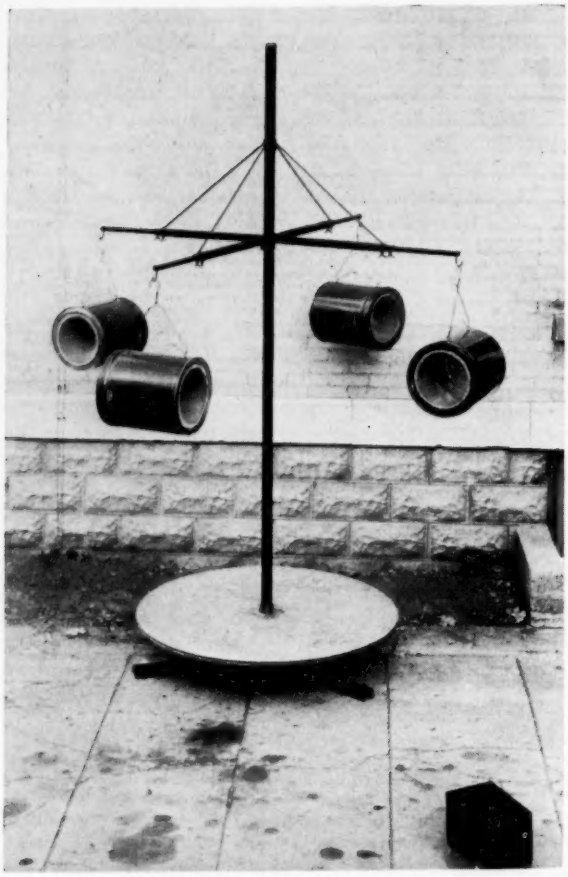

FIG. 2.—Mosquito-trap rotary with CO_2-baited traps. The drive mechanism, covered by sheet metal housing, is at the lower right.

wise to have a minimum length of exposed belt.

PROCEDURE.—All the tests of gnat baits were conducted in the same general way, some in Thomasville, Ga., some in nearby towns. They were started at various hours but were always finished before 6:30 p.m. on the same day. The preferred weather was clear with a very light breeze, but, in a few instances, testing was continued during rain. The speed of rotation in the apparatus as finally developed was one revolution in 5½ minutes. Excepting Tests 3 and 5, the length of the separate test periods was either 1 hour or 1 hour less the time needed to rearrange the bait dishes. The bait, usually one measure of a scoop holding about 25 ml., was poured into a deep petri dish, usually on a thick layer of absorbent cotton. Between the periods of a test, while the rotary was kept turning, the usual practice was first, to remove and close the collection jars; second, to remove all the bait dishes; third, to put the bait dishes in the correct traps for the next period; and fourth, to place on the traps the fresh collecting jars, already containing an identifying label.

In the rotary tests of mosquito traps made in Utah and California, the traps were suspended about 5 feet above the ground and rotated in a circle 6 feet in diameter. In the Utah tests, the speed of rotation was one revolution in about 4 minutes 40 seconds; in the California test, one revolution in about 5 minutes 40 seconds. Because *C. tarsalis* was known to have a peak of biting activity just after the fall of darkness (Beadle 1956), testing was started within one-half hour of sunset, and the separate periods of each test were conducted during the same hours on different nights.

Various methods were used to randomize the items tested. The items not being compared were usually kept at the same fixed positions on the rotary. The items under test were always randomly assigned to their original positions, and in the later tests each design was formed in a random manner, too.

All multiple-period tests have been evaluated by analysis of variance. To fulfill the condition that means and standard deviations vary independently, each number of gnats or mosquitoes, plus one, was transformed to its common logarithm. In the tests employing a Latin-square design it was possible to evaluate separately the effects of traps, baits, and periods of test. The importance of each of these sources of variation was determined by calculating an F-ratio whose level of significance was obtained from a table. The analysis of variance was supplemented in a few cases by comparison of individual means according to a method proposed by Tukey (1949). In the 6-period tests of baits in which traps were treated as a dummy variable, it was possible to study the effects of baits and periods only.

UNIFORMITY TESTS OF GNAT BAITS.—The first rotary test made June 30, 1950 was one of a long series of uniformity trials, each of which compared four samples of one bait. Suggestive but unsatisfactory results were obtained because each bait dish was kept in the same trap for all the periods of each test, and as it happened, there were slight differences among the traps. Promising results were not obtained until each bait dish was shifted, between test periods, to the trap which followed it on the turntable. It was at this point that Dr. Robert E. Serfling, of the Statistics Section, Communicable Disease Center, proposed that a Latin-square design be used to determine the successive positions of the bait dishes.

Using this type of design, a test made with a set of painted wooden traps compared four samples of bait from a weekly lot that was one of a few prepared without urea (table 1). This was the first successful uniformity trial (Test 1, Thomasville, Ga., Aug. 25, 1950). A second uniformity trial (Test 2, Thomasville, Ga., Sept. 10, 1950) used four of the newly developed metal traps (Dow & Hutson 1958) to compare four samples of a weekly bait mix prepared with urea. In both tests (table 1), the period-to-period differences in the catches did not appear to affect the F-ratios for traps or baits. Of interest and worth noting is the much lower F-ratio for metal traps than for wooden.

A third uniformity trial, consisting of four 2-hour periods, was made the following year (Test 3, Thomasville, Ga., July 24, 1951). The F-ratios for traps and bait dishes were small and not significant in the data for *H. pusio*. In this test, however, the catches included a large number of another member of the *pusio* group, *H. bishoppi* Sabrosky. One bait dish, which attracted far more than the average number of *H. pusio* in each of the last two periods, attracted the smallest number of *H.*

Table 1.—Results of uniformity trials, Georgia and Utah, 1950–54.

Test No.	Species	Totals Associated with Each Bait Container	F-ratio, Baits	Totals Taken in Each Trap	F-ratio	
					Traps	Periods
1	*H. pusio*	102, 102, 103, 105	0.35	58, 99, 107, 148	3.36	8.12*
2	*H. pusio*	406, 409, 482, 490	1.06	389, 414, 487, 497	1.50	19.8**
3	*H. pusio*	63, 65, 70, 93	0.91	57, 69, 78, 87	1.32	16.5**
3	*H. bishoppi*	53, 74, 74, 94	5.74*	56, 69, 70, 100	4.49	7.02*
4	*H. pusio*	36, 37, 39, 39	0.33	25, 37, 38, 51	1.93	5.37*
12	*C. tarsalis*	25, 35, 35, 41	1.32	19, 22, 47, 48	2.41	8.72*
13	*C. tarsalis*	40, 45, 46, 49	0.31	42, 43, 45, 50	0.57	7.76*

* Significant at 5% level.
** Significant at 1% level.

bishoppi in each of the last three periods. This inverse relationship between the two *Hippelates*, which approached significance in the test as a whole, is unique in the writer's experience. In consequence, the data for *H. bishoppi* give a significant F-ratio for baits and a nearly significant one for traps. Unfortunately this unusual situation was not recognized at the time of the test.

The fourth uniformity trial made with gnat traps (Test 4, Barwick, Ga., July 23, 1952) was part of a test designed to compare the gnat-trap rotary with sets of four traps in fixed positions on the ground. Besides the four traps on the rotary, there were 14 sets of traps at sites which were distant from natural attractants and widely distributed throughout the town. Each set of traps was arranged in a square with the sides toward the cardinal points of the compass. The spacing of these traps was identical with that on the 4-foot turntable of the rotary. A matured bait, thoroughly mixed, was used in all the bait dishes, and all the traps were operated, as nearly simultaneously as possible, for 4 hours. In the rotary test, though only 151 *H. pusio* were caught by the four traps, the F-ratios for baits and for traps were small and not significant (table 1). When the data for the rotary test were analyzed by chi-square on the assumption that each bait dish should attract equal numbers of gnats in each separate hour of the test, the catches associated with each bait dish did not differ significantly (probability lay between .05 and .10). On the other hand, the catches of the fixed traps differed significantly at 10 of the 14 sites (table 2).

Table 2.—Numbers of *H. pusio* collected in sets of fixed traps, with the values of chi-square and the probabilities (P) of larger values of chi-square than those observed, Barwick, Ga., July 23, 1952.

No. of *H. pusio* Taken in Trap at Indicated Position				Chi-square	P (3 d.f.)
NE	SE	SW	NW		
10	32	48	41	25	<.01
14	29	103	47	94	<.01
21	0	17	6	26	<.01
35	20	39	63	24	<.01
25	15	16	26	5	>.10
47	32	11	41	23	<.01
10	10	55	13	66	<.01
60	17	92	144	110	<.01
23	99	16	5	154	<.01
35	19	22	34	7	>.05
6	10	7	3	4	>.20
39	102	56	20	68	<.01
10	2	3	1	12	<.01
8	9	15	18	6	>.10

Tests of Different Gnat Baits.—*Effects of Dilution and of Exposure to Air.*—Directly after the third successful uniformity trial, a test was made of gnat baits so prepared that they could be expected to differ from each other (Test 5, Thomasville, Ga., Aug. 10, 1951). One dish with a scoop of liver bait taken after dilution with water to one-third of its original strength, and another dish with a scoop of the same bait, undiluted, were placed in traps outdoors late in the morning on August 9. The next morning these exposed bait dishes and two others, similarly but freshly prepared, were compared in a rotary test which employed a Latin-square design and consisted of four 1½-hour periods. Since it was expected that exposure of the bait would reduce its effectiveness through evaporation, the larger numbers of *H. pusio* caught by the exposed bait dishes were a complete surprise (tables 3 and 4). The fact that *H. bishoppi* reacted in the expected way showed that the two species of *Hippelates* were apparently reacting to different attractants. The diluted baits, whether exposed or not exposed, attracted fewer gnats of each species than the baits of full strength. The significance of the factors of dilution and exposure was demonstrated by partitioning baits as a source of variation and calculating separate sums of squares, each associated with one degree of freedom, for the two pairs of bait samples which differed in dilution and for the two pairs which differed in exposure. Dilution was found a significant source of variation at the 1% level for both species of *Hippelates*. Exposure was significant for *H. pusio* at the 5% level, and for *H. bishoppi* at the 1% level.

Table 3.—Analyses of rotary tests, Georgia, Utah, and California, 1951–55.

Test No.	Species	Factors Tested	F-ratios		
			Baits	Traps	Periods
5	*H. pusio*	bait: dilution, exposure	15.4**	0.65	2.12
5	*H. bishoppi*	bait: dilution, exposure	63.7**	0.70	3.54
6	*H. pusio*	bait: exposure	8.18**	—[a]	2.44
7	*H. pusio*	bait: exposure	7.41**	—[a]	0.24
8	*H. pusio*	bait: putrefaction	3.50*	—[a]	2.43
8	*H. bishoppi*	bait: putrefaction	0.53	—[a]	1.09
9	*H. pusio*	bait: material, wick	33.0**	0.55	24.1*
10	*H. pusio*	bait: material	24.9**	1.12	0.75
11	*H. pusio*	trap: design	0.32	1.51	12.6**
14	*C. tarsalis*	trap: baffle	4.38	25.9**	22.9**
15	*C. tarsalis*	trap: size, baffle	0.71	8.30*	2.65
16	*C. tarsalis*	trap: size, baffle	0.16	6.65*	1.03

* Significant at 5% level.
** Significant at 1% level.
[a] Traps here treated as dummy variable and omitted from analysis.

Table 4.—Rotary test of gnat baits differing in dilution and in duration of exposure to air, Test 5, Thomasville, Ga., August 10, 1951.

Strength of Bait	Bait Exposed Overnight	Total *Hippelates*	
		pusio	*bishoppi*
Full	Yes	551	66
One-third	Yes	245	37
Full	No	311	241
One-third	No	200	135

Table 6.—Six-period rotary test of liver bait matured under aerobic and anaerobic conditions, Test 8, Barwick, Ga., May 23, 1952.

Bait	Total *Hippelates*	
	pusio	*bishoppi*
Aerobic, sample A	265	40
Aerobic, sample B	121	42
Anaerobic, sample A	81	44
Anaerobic, sample B	42	43

The effect of exposing bait in a cage with gnatproof screening for different numbers of days was studied in Tests 6 and 7 (Barwick, Ga., May 5, 1952, and Boston, Ga., May 14, 1952). In Test 6 (table 5), an attempt was made to obtain similar samples of bait at different times by coring the frozen material. Each sample was exposed in a dish without cotton. On the morning of the test, the weight loss of each sample was replaced with water, and then the usual pad of cotton was placed in each dish. In Test 7 (table 5), after initial melting and stirring of all the bait, the second and later samples were taken from portions returned to temperatures below 0° C. In this test, the weight loss was not replaced with water, and no cotton was used in the bait dishes.

Both tests were conducted in six 1-hour periods. The purpose of adding two extra periods was to use a design that allowed each bait dish to follow each other bait dish an equal number of times (twice). Such a design does not permit each bait dish to be tested in each trap an equal number of times, but this condition loses its importance after the traps have been shown not to differ.

Both tests showed a rise in the attractiveness of the liver bait for *H. pusio* after 1 or 2 days of exposure to air. After 3 or more days of exposure, the attractiveness appeared to diminish (tables 3 and 5).

Aerobic vs. *Anaerobic Putrefaction.*—On April 29, 1952, a fresh mixture of ground pork liver, water, and urea, in the customary proportions, was placed in 1-quart glass fruit jars which were filled to within 1 inch of the lip and covered with lids, and in 1-gallon bottles and 2-liter Erlenmeyer flasks which were filled to a maximum depth of about three-quarters inch and covered with gauze only. The mixture in the closed jars was not shaken. It matured typically with the possible exception that an unusually large amount of gas was produced during the first 4 days. The mixture in the gauze-covered bottles and flasks, shaken on at least three occasions, was black sooner than in most of the jars. On the 24th day, in a 6-period rotary test, two samples of the anaerobically putrefied mixture in the jars were compared with two samples of the aerobically putrefied bait (Test 8, Barwick, Ga., May 23, 1952). Each of the aerobically matured samples attracted more *H. pusio* than either of the others (tables 3 and 6). All four samples of bait collected similar numbers of *H. bishoppi.*

Egg vs. *Liver Baits.*—In a report for February 1951, Tinkham (1951) mentioned as new a *Hippelates* bait made of raw egg in water. In September 1953, he obligingly sent the writer a sample of this bait which is prepared by whipping hens' eggs, adding them to water (four per quart), and stirring the mixture thoroughly. In his letter of transmittal, Dr. Tinkham wrote that the bait was used in the field immediately after mixing, and that it was sometimes poured into fresh dishes, sometimes added to old dishes of partly evaporated bait.

The first comparison of egg and liver baits (Test 9, Barwick, Ga., Sept. 5, 1953) tested each bait in an empty dish and also poured on cotton. Not only were the bait dishes significantly different in the numbers of *H. pusio* attracted (tables 3 and 7), but a breakdown of the data by type of bait and by manner of exposure showed that the liver bait was significantly more attractive than the egg, and that the bait dishes were significantly more effective without cotton.

The second comparison of egg and liver baits was made without cotton in the dishes (Test 10, Barwick, Ga., Sept. 7, 1953), and included samples of an egg bait mixed by the writer on August 17 and frozen at different intervals after its preparation. When these frozen egg baits were melted for the test, some of the material was observed to have formed a precipitate. There was again a significant difference among the bait dishes (tables 3 and 7), and the dish with the liver attracted significantly more *H. pusio* than any of those with egg. No conclusion

Table 5.—Six-period rotary tests of liver bait following its exposure for different numbers of days in gnat-free air, Barwick and Boston, Ga., May 1952.

Days of Exposure Before Testing	Test 6		Test 7	
	Per Cent Loss of Weight During Exposure	No. of *H. pusio* Trapped	Per Cent Loss of Weight During Exposure	No. of *H. pusio* Trapped
0	0	19	0	99
1	29	40	—	—
2	—	—	23	119
3	30	29	—	—
5	89	5	50	61
8	—	—	73	18

Table 7.—Rotary tests of gnat baits made from pork liver and from eggs, Barwick, Ga., September 5 and 7, 1953.

Type of Bait	Bait Tested on Cotton	Total *H. pusio*	
		Test 9	Test 10
Liver, frozen after 2 weeks	yes	180	—
Liver, frozen after 2 weeks	no	368	388
Egg, mixed in California on Aug. 31, not frozen	yes	30	—
Egg, mixed in California on Aug. 31, not frozen	no	60	65
Egg, mixed in Georgia, frozen on 3rd day	no	—	25
Egg, mixed in Georgia, frozen at end of week	no	—	134

can be drawn regarding *H. bishoppi* because only two specimens of this species were caught in each test. The two types of bait were not compared on a weight or cost basis.

DISCUSSION OF GNAT-BAIT TESTS.—In the tests of liver bait for *H. pusio*, the superiority of aerobic development is considered definitely related to the greater attractiveness of bait which has been exposed to gnat-free air. Indeed, there may be some biochemical significance in the fact that the natural attractants of *H. pusio* occur on exposed epidermal tissues. The finding that the captures of *H. bishoppi* were not affected by the way in which the bait was matured (table 6) and were actually reduced as a result of its exposure (table 4) is considered good evidence that the bait contains two quite different attractants. A bait specific for *H. pusio* would be very desirable because every method of analyzing trap collections that contain mixtures of *H. pusio* and *H. bishoppi* is more or less time-consuming (Dow & Hutson 1958). The studies were terminated before tests could be made on fractions of the standard bait. Such an analysis might have suggested synthetic compounds worth testing and it might have led to the identification of the basic attractant of *H. pusio*.

TESTS OF DIFFERENT MODELS OF GNAT TRAPS.—The only four-period test of different types of gnat traps compared the wooden trap used for prevalence trapping in 1950 with the metal trap developed in that year (Test 11, Thomasville, Ga., Sept. 14, 1950). The two types of traps were placed in alternating sequence on the turntable and kept in these positions, while the bait dishes, containing samples of one bait, were rearranged for each period of the test in accordance with a Latin square. The two metal traps caught totals of 126 and 97 *H. pusio*, and the two wooden traps totals of 106 and 69. There was no significant difference among either the bait dishes or the traps (table 3). This outcome may have resulted from operating the traps in fixed sequence. On the other hand, when the metal and wooden traps were tested without rotation, the metal were clearly superior. It is suspected, therefore, that the rotary may have compared only the catching and holding success of the four traps, that the real advantage of the metal trap is its ability to produce a greater amount of bait odor, and that the release of attractant could not be compared quantitatively in traps rotated in so small a circle.

UNIFORMITY TESTS OF MOSQUITO TRAPS.—A portable mosquito bait-trap developed by R. E. Bellamy & W. C. Reeves (1952) was originally made from a 50-pound lard can and baited with a block of solid carbon dioxide (dry ice) which had been wrapped in paper. Apparent irregularities in the catches of this trap when operated in 1953 by the U. S. Public Health Service in Mitchell, Neb., made it desirable to investigate the source of the variation. Before any rotary tests were made, it was learned that dry ice, suitably insulated in cartons manufactured to hold liquid food, would produce CO_2 at a very uniform rate. The ideal container was found to be a tapered 1-pint carton fitted into a second tapered carton of 1-quart capacity. The volume of gas released by this dispenser during Tests 12 to 15, conducted at an elevation of 4,500 feet above sea level, was calculated as approximately 450 cc. per minute.

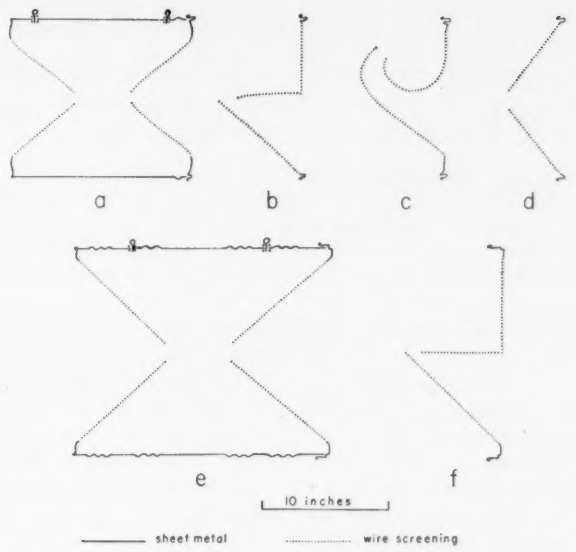

FIG. 3.—Median vertical longitudinal sections of small (a) and large (e) lard-can mosquito traps, and of covers of small (b,c,d) and large (f) traps to show the various types of baffle tested: a, standard; b and f, Egyptian; c, reflexed; d and e, modified standard (both with large openings).

When four small lard-can traps baited with double-carton CO_2 dispensers were subjected to uniformity trials, both the first and second tests were satisfactory (Tests 12 and 13, Logan, Utah, July 8 to 12 and 17 to 23, 1954). In the first test, the traps were operated from 8 p.m. to about 5 a.m. daily, but in the second, each of the four periods ran from 7:30 to 11:30 p.m. A Latin-square design was used to rearrange the sequence of the bait dispensers in the first test, and of the traps in the second (table 1).

From the results of later tests, it is now believed that the quantity of CO_2 released by each of the bait dispensers may have exceeded the amount which would produce the maximum response on the part of *C. tarsalis*. If this is so, the similar catches of *C. tarsalis* might indicate only that the traps were equally efficient. For a satisfactory uniformity trial, the quantity of CO_2 released should be within the range producing a variable response so that similar numbers of *C. tarsalis* would show that the dispensers were alike. Even if Tests 12 and 13 were deficient with respect to attractants, they were valid with respect to traps because another baffle was subsequently shown to be more effective than the standard.

TESTS OF DIFFERENT MOSQUITO TRAP BAFFLES.—To increase the catches of *C. tarsalis* in the lard-can traps, an attempt was made to improve the standard baffle (fig. 3a). One of the new designs (fig. 3b) was adapted from the horizontal baffle of a stable trap developed in Egypt by Bates (1944), another had a reflexed entrance (fig. 3c), and another was like the standard cone but more shallow, of greater diameter, and with a larger opening, 23/16 inches in diameter (fig. 3d). Traps with these three new baffles were compared with one of the standard traps used in the uniformity trials (Test 14, Cache Valley, Utah, July 30 to Aug. 2, 1954). The test was run in four 3-hour periods starting about 7:15 p.m. As in all the tests

Table 8.—Rotary tests of baffles in two sizes of CO_2-baited lard-can traps, Cache Valley, Utah, August 13 to 20, 1954, and Kern County, Calif., June 27 to 30, 1955.

Size of Trap	Baffle	Total *C. tarsalis*	
		Test 15	Test 16
Small	Standard	13	26
Small	Egyptian	45	113
Large	Modified standard	57	80
Large	Egyptian	98	130

of different baffles, the bait was CO_2 released by dry ice put in double cartons. The standard trap caught a total of 174 *C. tarsalis;* the second, with Egyptian baffles, 386; the third, with reflex baffles, 87; and the fourth, with modified standard baffles, 105. They were significantly different as a group (table 3), the trap with Egyptian baffles was significantly better than the standard, and the standard was significantly better than the trap with modified standard baffles.

The next test (Test 15, Cache Valley, Utah, Aug. 13–20, 1954) compared traps made from large (120-pound) as well as small lard cans, each size with both standard and Egyptian baffles (fig. 3, a, b, e, f). Though the traps differed significantly (tables 3 and 8), there was doubt about the ranking of the two traps which caught intermediate numbers of mosquitoes. The test was therefore repeated the next summer (Test 16, near Buttonwillow, Kern Co., Calif., June 27–30, 1955). Again the traps differed significantly, but the rank of the two intermediate traps was reversed. In spite of the uncertainty regarding these two models, when the variance due to traps was partitioned, the two types of baffle were found to be significantly different in both tests, but the two sizes of trap were significantly different in the first test only.

One other comparison of these baffles (Test 17, Cache Valley, Utah, Sept. 11, 1954) was made as a special one-period test. The night of September 10 to 11, *C. tarsalis*, which had been collected in resting places during the day, were placed in the four traps, a few specimens at a time, until each contained 42 females. The traps were then taken to the field, set in motion on a rotary, and opened at 1:40 a.m. The following morning was hot, dry, and windy, and the traps, still rotating, were closed at 10:20 a.m. The large and small traps with the standard type of baffle had lost 2 and 1 specimens, respectively. The large and small traps with the Egyptian baffles had lost 14 and 11 specimens, respectively. It was concluded that the Egyptian baffle could not be used without some device to kill and hold the trapped mosquitoes.

General Discussion of Method.—*Use of Method by Other Workers.*—The rotary test developed in the course of the writer's studies has two essential features: the horizontal rotation of test items, and the use of statistical designs to control undesirable variation. The rotation of the test items is not to be confused with the rotation of identical catching devices, usually at different heights above the ground (Chamberlain & Lawson 1940). The feature of rotation was not new, however, as it had been used by Dr. Don E. Eyles to test various modifications of New Jersey light traps at least as early as 1941. Eyles (1955) compared only two items at a time in a one-period test, but he employed the concept of the uniformity trial and made chi-square analyses of his results.

Another rotary device for testing various responses of mosquitoes was developed by Edgar & Herndon (1957). In this apparatus the test items are exposed in a single block of six compartments. These form a hexagonal carrousel which is open on each side. The results so far published do not establish whether this compact and rigid arrangement of the experimental units is successful in tests that involve factors related to olfaction only.

Still another rotary was built to compare the responses of mosquitoes to colored lights of equal intensity (Bargren & Nibley 1956). The New Jersey light traps used in these experiments were rotated in a circle 20 feet in diameter. Unfortunately the report on this excellent study does not give a full account of the careful work done on its design and analysis.

Selection of Statistical Design.—When a rotary test is to be made with baited traps and there is no reliable information on the behavior of either the trap or its attractant, the use of a Latin-square design provides a means of separating and measuring the variation due to each element (traps, baits, and periods). With a Latin-square design it is conceivable that traps which show slight but consistent differences could be used to evaluate a set of different baits. Ideally, of course, there would be a minimum of disparity in the elements not under test, for when an element does not contribute significantly to the total variance, it can be omitted from consideration in the design and the result is a statistically stronger test. Thus, for example, once it had been established that the four gnat traps used in Tests 2 to 11 were essentially identical, there was no need to treat traps as a variable and each analysis could have been based on baits and periods alone. Such a two-way design is superior statistically because it increases the number of degrees of freedom available for error. This reduces the chance of making a Type II error, that is, of missing a real difference in the items under test.

A two-way design, evaluating periods and either baits or traps as sources of variation, is more flexible than a Latin square. If necessary, the number of periods can be increased until there are enough data to reach a satisfactory conclusion. Another advantage is that each possible sequence of two items can be tested an equal number of times. This is never possible with a Latin square in which, moreover, all the symbols may happen to fall in the same order in each row, so that in a test based on such a square, all the test items would be rotated in the same sequence in each successive period. That there is danger in such repetition is indicated by two tests. In Test 11, the traps that were being compared were kept in the same positions throughout, and in Test 8, although the bait dishes under comparison were shifted between the periods to other traps, they stayed in the same order for four periods. In both tests, pairs of items that were supposed to be different caught overlapping numbers of *H. pusio*. These results suggest that the success of a given trap in a given period may be quite strongly affected by its spatial relation to the other traps on the rotary. Consequently, in selecting a design for a rotary test, the repetition of sequences should be avoided as far as possible,

and sequences of two items which must be repeated should occur equal numbers of times.

Advantages of Rotary Tests.—In addition to the primary function of reducing site differences, the use of a rotary has several attractive features. Tests can be made outdoors with wild populations under more or less natural conditions. They can be used to evaluate even a single model of a new trap or bait dispenser, or a very small quantity of a candidate bait. A test can be conducted by one person in a few short periods, and the observations, once tabulated, can be analyzed in less than an hour. With flexible equipment, rotary tests should be useful in the study of any animal that flies to the source of an airborne attractant. A rotary can also be used to trap equivalent samples of wild populations.

REFERENCES CITED

[**Bargren, W. C.**, and Carlyle Nibley, Jr.] 1956. Comparative attractiveness of colored lights of equal intensity to specific species of mosquitoes. Res. Rept., Third Army Med. Lab., Fort McPherson, Ga. 42 pp.

Bates, Marston. 1944. Notes on the construction and use of stable traps for mosquito studies. Jour. Natl. Malaria Soc. **3**: 135–45.

Beadle, L. D. 1956. Man-biting habits of *Culex tarsalis* and associated mosquitoes in northern Utah. Abst. and Proc. 8th Ann. Meeting Utah Mosquito Abatement Assoc., 1955: 3.

Bellamy, R. E., and W. C. Reeves. 1952. A portable mosquito bait-trap. Mosquito News **12**: 256–8.

Chamberlin, J. C., and F. R. Lawson. 1940. A mechanical trap for the sampling of aerial insect populations. U. S. Dept. Agric., Bur. Ent. and Plant Quar. **ET-163.** 6 pp.

Dow, R. P., W. C. Reeves, and R. E. Bellamy. 1957. Field tests of avian host preference of *Culex tarsalis* Coq. Amer. Jour. Trop. Med. and Hyg. 6(2): 294–303.

Dow, R. P., and G. A. Hutson. 1958. The measurement of adult populations of the eye gnat, *Hippelates pusio*. Ann. Ent. Soc. America **51**: 351–60.

Edgar, S. A., and J. F. Herndon. 1957. A rotary insect-preference trap. Mosquito News **17**: 14–17.

Eyles, D. E. 1955. Personal communication.

Hess, A. D., and Preston Holden. 1958. The natural history of the arthropod-borne encephalitides in the United States. Ann. New York Acad. Sci. **70**(3): 294–311.

Tinkham, E. R. 1951. February 1951 report on eye gnat research and control. Coachella Valley Mosquito Abatement District, Indio, California. 6 pp.

Tukey, J. W. 1949. Comparing individual means in the analysis of variance. Biometrics **5**: 99–114.

Williams, C. B. 1951. Comparing the efficiency of insect traps. Bull. Ent. Res. **42**: 513–7.

Williams, C. B., R. A. French, and M. M. Hosni. 1955. A second experiment on testing the relative efficiency of insect traps. Bull. Ent. Res. **46**: 193–204.

Biology and Economic Status of *Hylemya fugax* (Meigen) in Oregon[1]

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ABSTRACT

Hylemya fugax (Meigen), an anthomyid fly closely related to the seed-corn maggot, has been reported as a leaf miner, a pest of cauliflower heads, and as a saprophagous secondary invader of various crops. Observations show that this species is more abundant in Oregon than previously thought and that it is active in the field from March through November. Studies on cauliflower have implicated *fugax* with the discoloration of the heads, but only incidentally as a result of its saprophytic habits.

The anthomyid fly, *Hylemya fugax* (Meigen), is a widely distributed species in Europe and has been known in the eastern United States since at least 1924. Cole and Lovett did not record this species in their annotated list of Oregon Diptera published in 1921. In 1931, however, Dr. Don C. Mote, former Head of the Entomology Department at Oregon State College, issued an Experiment Station Memorandum to the effect that *H. fugax* was a heretofore unrecorded pest of cauliflower. The injury was reported as done by the larvae which fed on the surface of cauliflower heads producing a rusty or yellowish brown surface. Since this time, reports of cauliflower-head maggots have reached the College on several occasions. The purpose of this paper is to review the literature and to report the results of observations and experiments pertaining to the biology and possible economic status of *H. fugax* in Oregon.

Frost (1924), in his study of the leaf-mining Diptera of North America, discusses *fugax* as a "fairly common miner on the leaves of spinach and beet and on the leaves of several weeds." Actually his observations and rearing data do not support his belief that this species is a primary leaf miner since *Hylemya* [=*Pegomyia*] *hyocyami* (Panzer), the spinach leaf miner, was also reared from the same beet and spinach leaves and was usually the more abundant. Earlier literature discussed by Frost involves *H. betae* (described by Holmgren in 1880 and made a synonym of *fugax* by Malloch in 1920) mining in beet leaves in Sweden, and a second species, *H. betarum* Lintner, that also mines in beet leaves. Huckett (1924) states that *betarum* is very similar to, but distinct from, *fugax*. The confused synonymy of the group makes uncertain the identity of the species involved in these early reports.

Although earlier *fugax* was reported mining in the leaves of spinach, beets, carnations (Van Poeteren 1945), and other plants, most of the later records associate it with cruciferous crops. Smith (1927) reported *H. brassicae*, the cabbage maggot, and another species of anthomyid tunnelling in *Brassica* roots, which, judging from his description of the posterior bifid tubercle and spiny cuticle, was undoubtedly *H. fugax*. Smith did not rear the adults, but described the habits of the fall generation as laying eggs in leaf axils, on leaves, and on the

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heads of cauliflower. The presence of *fugax* larvae in Brussels sprouts, often in the absence of *H. brassicae* larvae, was noted by Webley (1949) in England. A bacterial rot of the sprouts was, however, occasionally noted in association with the maggots.

H. fugax has been collected from cauliflower roots, turnips, rutabagas, and Brussels sprouts in Canada (Brooks 1951, Forbes 1955). Mary Miles (1950) reported collecting larvae of *fugax* from most of the common cruciferous crops and lettuce in England. Miles also points out that the larvae were taken from the "curds" of cauliflower, but that in all her observations of this species' attacking plants it was invariably associated with other insect species or with damaged and decomposing plant tissue.

Studies on the cabbage maggot, *H. brassicae* (Bouché), in Corvallis during 1949–50 revealed the presence of both *fugax* and *brassicae* larvae in the bases of cabbage heads. In 1953 a number of late cauliflower fields in the Portland area were found infested with maggots. Considerable loss was incurred because of the discoloration or russeting of the curd. Several larvae of *fugax* and one *brassicae* were collected from the cauliflower heads during a period of rainy weather and it was felt at the time that the high-water table had induced the flies to oviposit higher on the plants than normal.

A series of observations in the Willamette Valley since 1947 have revealed that *H. fugax* is much more common than previously suspected and that it is of economic importance in the culture of cauliflower.

FIELD RECOGNITION.—The various stages of *H. fugax* can be recognized rather easily with the aid of medium magnification, with the exception of the adult female.

EGGS.—The eggs of *H. fugax* are easily distinguished from those of other Diptera found around cruciferous plants or decaying vegetation. Magnification shows the distinctive reticulated pattern of the chorion and presence of a ventral groove running the entire length of the egg (Miles 1952).

LARVAE.—The maturing larvae of *fugax* can be distinguished from those of any other species found in the same habitat by the presence of large conical tubercles around the posterior spiracular area. These tubercles can be seen with the naked eye in good light. Additional characters are the minute spicules covering the larval skin, and the presence of one bifid tubercle in the median posterior area.

ADULTS.—Of the common species of anthomyids, *Hylemya cilicrura* (Rond.), the seed-corn maggot, is most likely to be confused in the adult stage with *H. fugax*. Absence of the conspicuous fringe of hairs on the hind tibiae of male *fugax* easily separates it from male *cilicrura*. Female *fugax* may be identified with some difficulty by their green-gray color and by the presence of a sparse pubescence on the arista, which is lacking in *cilicrura*.

PREVALENCE OF *H. fugax* IN THE WILLAMETTE VALLEY.—In the Oregon State College collection, *H. fugax* is represented by 19 different collection dates and from locations ranging the length of the Willamette Valley. The earliest record is from Corvallis on August 22, 1924. Adults have been taken in all the months from March through November.

A survey was made at Corvallis in the spring of 1952 to determine the relative abundance of *fugax* adults as compared with cabbage-maggot and seed-corn maggot flies. Blooms of wild mustard (*Brassica campestris*) were swept at weekly intervals from April 13 to May 5. The anthomyids collected were determined by Mr. C. W. Sabrosky, of the Insect Identification Laboratories, Entomology Research Division, U. S. Department of Agriculture. During this period about 67% of the anthomyids present were *fugax*. A record of anthomyids collected in this survey is given in table 1.

Emergence studies at Corvallis in the spring of 1949 revealed that there were as many as or more *fugax* than cabbage maggots (*H. brassicae*) overwintering in old crucifer plantings. Eighty-seven per cent of the anthomyids emerging from an old broccoli planting were identified as *H. fugax*.

The site of a cauliflower field in the Portland area, heavily infested with *fugax* in the late fall of 1957, was observed for anthomyid adults in mid-May of 1958. Sweeping the weeds at the edges of the field produced 19 flies, 15 of which were *fugax* and 4 *H. cilicrura*. Onion fields apparently produce conditions favorable for this insect at times. Eggs of *fugax* have been found on rotting onions, and sweeping the borders of an onion field near Salem produced two *fugax* females, one onion maggot, and one undertermined anthomyid adult on May 9, 1958.

SPRING EMERGENCE OF ADULTS.—*Hylemya fugax* is known to overwinter as a puparium in the soil or closely associated plant refuse (Miles 1950). Spring emergence of the flies was studied in 1948 and 1949 in connection with cabbage-maggot control work at Corvallis. *H. fugax* was found to vary slightly from *H. brassicae* in both the timing and duration of the emergence period of the spring brood of flies.

In 1948, conical traps were placed over old radish rows on February 26 and emerged flies removed at 1- to 3-day intervals until May 29. Specimens in good condition were submitted to the Insect Identification Laboratories for determination. From these data it was found that *fugax* started emerging March 27 with the peak (50% emergence) falling on April 11. *H. brassicae* did not appear until April 13 and reached its peak of emergence almost 2 weeks after *fugax*.

Observations on emergence were repeated in 1949 with cages being placed over old radish, turnip, and broccoli plantings on March 9. By April 22, when observations were terminated, 120 anthomyids had been collected, 64% of which were *fugax*. Emergence of *fugax* began March 23 and was 5 to 9 days ahead of *brassicae* in the three collection sites.

No surveys have been made in Oregon to determine the number of generations or the preferred breeding sites of

Table 1.—Adult anthomyid flies swept from wild mustard blooms. Corvallis, Oregon. 1952.

SPECIES OF *Hylemya*	NUMBERS OF FLIES COLLECTED ON				
	Apr. 13	Apr. 20	Apr. 27	May 5	Total
fugax	22	14	7	2	45
cilicrura	5	3	2	0	10
brassicae	5	2	0	0	7
spp.	2	0	0	3	5

fugax during different seasons of the year. Since adults have been taken from March through November, there are probably several generations. Miles (1950) suggests three or four generations occur in England.

LATE SEASON OBSERVATIONS OF *H. fugax* ON CAULIFLOWER.—A routine check of commercial cauliflower fields during a cool rainy period in mid-November, 1957, revealed one field near Portland with all stages of *H. fugax* present on the heads and foliage. Insect control had been neglected in this field and it had finally been abandoned for further harvesting because of the discolored curds (fig. 1). No larvae of *fugax* could be found in other fields in the same area where good aphid and cabbageworm-control programs had been followed. A more thorough examination of the plants in the infested field on November 20 brought out a number of interesting features.

Nine cauliflower heads were cut and dissected carefully. From 8 to 27 maggots were found on every head, averaging 18 per head. The curds were considerably discolored, none being suitable for market. Examination of the foliage revealed more larvae, many of them second instar or younger, along the petioles of the leaves where quantities of cabbageworm frass, dead insects, and aphid parts had accumulated. No indications of maggot feeding on or in the leaves and stems could be found.

Eggs and egg chorions were abundant, laid singly and without adhesion to leaves. Several live *fugax* females were taken, seeking shelter in the foliage from the rain. Dissection of the flies disclosed two with maturing eggs and one with eggs mature enough to show the identifying characteristics.

The same field was examined again about a month later (December 17). In a sample of 10 cauliflower heads, an average of only 6 maggots was found, and several pupae were discovered at the bases of the leaf petioles just below the heads. No eggs or flies were seen. Although the weather was relatively mild at the time, two or three light frosts had occurred since the last inspection of the field.

H. fugax thus appears to be active late into the fall—probably until freezing weather. The presence of the eggs and larvae in the leaf axils in association with cabbageworm frass, cast aphid skins, and other debris, strongly supports Mary Miles' conclusion concerning the saprophytic habits of this species. One factor needed clarifying, however, *i.e.*, the relationship between *fugax* larvae and discoloration or russeting of the cauliflower curd.

EFFECT OF *H. fugax* LARVAL FEEDING ON CAULIFLOWER CURDS.—Arrangements were made with a grower in the Portland area to conduct an experiment on newly matured cauliflower plants which had been kept relatively free of lepidopterous larvae and aphids during the 1957 growing season. Maggots were collected from the infested field, checked for identity as *H. fugax*, and then divided into 5 groups of 11 larvae each. Ten plants were selected for firm white curd in the clean field and five of these plants infested with maggots. This was accomplished by merely flushing the larvae onto the cauliflower head with a little water. The long, top leaves were then tied over the infested heads, as well as over the five untreated checks, to protect them from the weather.

One week later (December 26) the 10 heads were cut and taken to the laboratory for examination. A count was made of the number of maggots present and the number of individual curd sections in each head which showed the typical russeting. Twenty-five maggots were recovered from the infested cauliflower heads, and four were found, occurring naturally, on one of the check heads. All five infested heads were heavily russeted, while only two checks showed slight indications of discoloration.

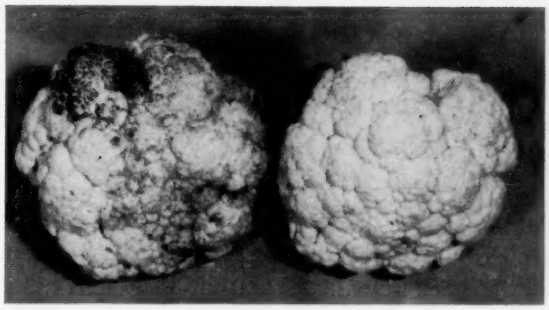

FIG. 1.—Cauliflower head, discolored by feeding of *Hylemya fugax* (Meigen) larvae, compared with a normal head. Corvallis, Oregon. 1957.

In all, 46 curd sections of the treated heads were russeted, and only four sections in the checks were discolored. Two of these four sections were on the head having the four naturally occurring maggots. In view of the above observations, it would appear that larvae of *Hylemya fugax* are capable of producing primary injury to cauliflower heads in the form of discolored curds. The presence of the larvae on the heads, however, is associated with the presence of other crucifer pests. Insect frass, cast skins, and micro-organisms probably make the plants attractive to the ovipositing females and must serve as the normal food for the larvae. While attempting to pick up decaying organic matter on the surface of the curds the larvae scrape the delicate epidermal tissue, resulting in the discolored or russeted spots.

REFERENCES CITED

Brooks, A. R. 1951. Identification of the root maggots (Diptera: Anthomyiidae) attacking cruciferous garden crops in Canada, with notes on biology and control. Canadian Ent. **83**: 109–20.

Cole, F. R., and A. L. Lovett. 1921. An annotated list of the Diptera (flies) of Oregon. Proc. California Acad. Sci. 4th ser. **11**: 197–344.

Forbes, A. R. 1955. The root maggot complex (Diptera: Anthomyiidae) in cruciferous crops of the Pacific Northwest (unpublished M.S. thesis., Oregon State College).

Frost, S. W. 1924. A study of the leaf-mining Diptera of North America. Cornell Univ. Agric. Expt. Sta. Mem. **78**: 1–128.

Huckett, H. C. 1924. A systematic study of the Anthomyiinae of New York, with especial reference to the male and female genitalia. Cornell Univ. Agric. Expt. Sta. Mem. **77**: 3–91.

Miles, Mary. 1950. Studies of British anthomyiid flies, I-II. Bull. Ent. Res. **41**: 343–54.

Miles, Mary. 1952. Studies of British anthomyiid flies, III. Bull. Ent. Res. **43**: 83–90.

Smith, K. M. 1927. A study of *Hylemya* (*Chortophila*) *brassicae* Bouché, the cabbage root fly and its parasites. Ann. Appl. Biol. **14**: 312–30.

Van Poeteren, N. 1925. Verslag over de Werkzaamheden van den plantenziektenkundigen Dienst in het Jaar 1924. Verslag. & Meded. Plantenziektenk. Dienst, 41, 62 pp. (R.A.E. (A), **13**: 362).

Webley, D. 1949. *Pegohylemyia fugax* Meig. (Diptera: Muscidae) attacking Brussels sprouts. Entomologist's Monthly Mag. 4th ser. (**113**): 132.

On the Improbability of *Bacillus thuringiensis* Berliner Mutating to Forms Pathogenic for Vertebrates[1]

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ABSTRACT

On the basis of theoretical considerations, as well as experimental evidence, there appears to be little reason to believe that crystalliferous *Bacillus thuringiensis* Berliner and its close varieties as they occur in properly prepared microbial insecticides are likely to mutate spontaneously into forms pathogenic for vertebrates. Similarly, on the basis of our present-day understanding of bacterial genetics, it appears that such mutations are not very likely with most of the truly entomogenous bacteria. At least, the possibilities in this regard do not appear to be sufficient to preclude the use of adequately tested entomogenous microörganisms for pest control purposes. Nevertheless, safeguards should be maintained to detect such events should they occur.

Following the publication of our paper (Steinhaus 1957) on the harmlessness of insect pathogens and the standardization of microbial control products, we received numerous inquiries relating to the possibility of entomogenous bacteria mutating into forms pathogenic for vertebrate animals or for plants. In the paper referred to, we did deal briefly with this subject saying that, from the evidence at hand, the likelihood of harmful mutations occurring appears to be remote. The purpose of the present paper is to corroborate this statement and to present additional reasons for its validity. It is hoped that a further consideration of the matter will help provide at least tentative answers to some of the questions in the minds of those who anticipate using microbial control products, such as the spore preparations of *Bacillus thuringiensis* Berliner, that are about to appear on the market.

Most of the queries we have received have been concerned with *B. thuringiensis* probably because, except for the toxic proteinaceous crystal it produces during sporulation, it is difficult to distinguish from the common soil organism *Bacillus cereus* Frankland and Frankland which, in turn, is taxonomically related to *Bacillus anthracis* Cohn, the cause of anthrax. Some of the apprehension has been based on the fear that *B. thuringiensis* might somehow change into *B. anthracis* or an *anthracis*-like form. Also, while it is reassuring that during the past century's work with insect pathogens no mutants harmful to man are known to have appeared, it is also true that much wider use of entomogenous microörganisms as control agents is now anticipated. Such prospects certainly warrant a close examination of possible harmful or undesirable consequences. Will such intensive use, for example, dangerously increase the likelihood of harmful mutants arising following the application of a microbial insecticide?

On the basis of all the evidence presently available, and on the basis of present-day knowledge of microbial genetics, the best-informed answer to such questions is, as we have indicated, one of assurance that the fears expressed are probably unnecessary. To be sure, from a scientific point of view, and because we really know very little about the genetics of virulence, it would be illogical to maintain that strains of truly entomogenous microörganisms could not mutate into forms pathogenic for vertebrates, but it does appear that chances of such a change occurring are exceedingly small, and not sufficient, in the case of *B. thuringiensis*, to prohibit its use as a biotic insecticide. There is probably *some* risk associated with the introduction of *any* new control agent, biological or chemical, into our environment. For example, one person in a million may be sensitive to a new chemical insecticide—a sensitivity that in all likelihood would not be picked up in preliminary safety tests; but this would not preclude the wide use of the product. All manner of safety tests[3] have so far failed to reveal any indication that *B. thuringiensis* has any pathogenicity for vertebrates, and it would seem that the likelihood of *B. thuringiensis* mutating into *B. anthracis* is probably no greater than that of *Streptococcus lactis* (Lister) Löhnis, as used in dairy products, changing into *Streptococcus pyogenes* Rosenbach, a common pathogen of man. It is assumed, of course, that the proper precautions are taken during the manufacture of microbial insecticides to prevent their contamination with vertebrate pathogens or, indeed, with other microörganisms of any kind. Furthermore,

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[2] In considering the matters discussed in this paper I have consulted with several of my colleagues including Drs. Werner Braun, Eric R. Brown, Joshua Lederberg, M. D. Moody, Francis J. Ryan, and C. W. Smith, all authorities in the field of microbial genetics. In preparing my remarks I have made free and extensive use of their criticisms, counsel, and advice, but this does not imply any responsibility on their part for the content or manner in which the facts and ideas in this paper are presented. I am grateful to them for their interest and help in the theoretical and factual examination of this important question highlighted by recent advances in applied insect pathology. I am also grateful to Drs. C. G. Thompson, T. A. Angus, and A. M. Heimpel for their helpful comments and suggestions.

[3] While some of these pathogenicity tests in vertebrates have been conducted in our laboratory (see Steinhaus 1951), we refer here also to extensive tests run by Bioferm Corporation, Wasco, California, and by Dr. Eric R. Brown (to be mentioned later), and communicated to us in correspondence. The results of the Bioferm ingestion and inhalation tests have been reported before the American Chemical Society meeting in Boston, Massachusetts, April 7, 1959, in a paper titled "Toxicology of the Microbial Insecticide, Thuricide," by Robert Fisher and Lawrence Rosner.

throughout this paper it is being assumed, in light of recent taxonomic work by Heimpel and Angus (1958), that *B. thuringiensis* is a true and well-established species, distinct from *B. cereus*.

THEORETICAL CONSIDERATIONS.—In the first place it must be realized that the fact that *Bacillus thuringiensis* and *Bacillus anthracis* have been placed by taxonomists in the same genus may have very little connection with the genetic potentialities and relationships of the two species. Certainly the ecological niche to which *B. thuringiensis* is adapted would appear to be more significant than the taxonomic grouping involved. Similarities in bacterial characteristics employed for taxonomic purposes do not necessarily mean a great deal regarding the degree of natural, or genetic, relationship among the species involved. From a genetic standpoint bacterial classification may be highly artificial.

It is generally considered that naturally occurring pathogens are relatively stable in the genetic sense; which means that their specific survival value within a given environment may reflect the gradual accumulation of a series of genetic determinants making the strain concerned specifically fit to multiply in its particular natural environment. To obtain a variant with high fitness to an entirely different environment it would now be necessary that there occur appropriate changes in several determinants rather than just one genetic alteration, in order to change the avirulent type into a type pathogenic for vertebrates. Since it is known that genetic determinants change at relatively low rates the probability of the occurrence of a series of the changes required to make potential variants fit for another environment would be exceedingly low.

As pointed out in our previous article, the situation should not be confused with what happens when avirulent strains of known vertebrate pathogens suddenly give rise to virulent strains. Such spontaneous changes (occurring at exceedingly low rates) in the pathogenicity of bacteria involve a one-step loss in, or restoration of, pathogenicity, usually similar to those existing in the original population, and following a limited period of cultivation. In a personal communication, Werner Braun has reminded us that in nature well-established avirulent "species" probably have had, superimposed upon the loss of one or more determinants, so many modified mutations that the likelihood of reversion is practically nil, since it now requires a series of mutational events each of which, to begin with, is exceedingly rare. It can also be suspected that some of these changes may have to occur in proper sequence to yield viable progeny, thus further contributing to the rareness of such changes and the relative stability of many naturally occurring avirulent "species," or of well-established "species" with restricted host ranges. Thus it would appear that in all probability since more than one change (at exceedingly low frequencies) is required to convert an insect pathogen into a vertebrate pathogen, the likelihood of two or more such required simultaneous changes, or even of proper sequential changes, occurring would appear to be highly improbable. Especially improbable would be the chances of this happening directly following the application of a properly prepared and tested microbial insecticide.

Most known cases of reversion in bacteria have occurred in the laboratory and only after having been genetically manipulated to bring about this state. Most such reversions require the use of special media, growth conditions, bacteriophages, et cetera, which are not readily met by conditions in the field. Nature requires aeons of time to bring this about, so that the odds of arranging hundreds of factors within a gene, let alone adding those necessary to make up a set for a particular pattern of pathogenicity are tremendous.

EXPERIMENTAL DATA.—In a recent study involving the differential diagnosis of *Bacillus cereus* and *Bacillus anthracis*, Brown *et al.* (1958) presented data on the artificial selection of pathogenicity in *B. anthracis* resulting from serial passage on a blood-glucose medium. After growing 28 strains of *B. cereus* on this medium, they found 28 to be pathogenic for mice, 21 pathogenic for guinea pigs, and 14 pathogenic for rabbits. The question naturally arises, what would the similar handling of *B. thuringiensis* strains on such artificial media do as far as their pathogenicity for vertebrates is concerned? Of particular value would be data obtained by the same worker using the same techniques as used with the *B. cereus* strains.

To obtain information on this matter, we consulted with the authors of the paper to which we refer, and received assurances that there is no conflict between the data presented in their paper and the thesis being presented in the present paper. Dr. Eric R. Brown kindly made available to us additional data which we have his permission to summarize here. Prior to our consulting with Dr. Brown, he had tested eight strains of *B. thuringiensis* and found none of them pathogenic for vertebrates. Later he tested 17 additional strains and none of these were virulent under the conditions reported in the paper by him and his colleagues.

Subsequent to these tests, we sent Dr. Brown the "type" strains of *B. thuringiensis* var. *thuringiensis* Berliner, *B. thuringiensis* ("Anduze" strain), *B. thuringiensis* var. *sotto* (Aoki & Chigasaki), *B. thuringiensis* var. *alesti* (Toumanoff & Vago), *B. entomocidus* var. *entomocidus* Heimpel & Angus, and *B. entomodicus* var. *subtoxicus* Heimpel & Angus. These strains were treated in a manner similar to that referred to in their paper (*i.e.*, cultured on blood-dextrose medium), and with proper controls, tested for pathogenicity in mice (four per strain). Except for two deaths occurring immediately after inoculation, and judged not to be caused by the bacillus, none of these strains, even after cultivation on blood-dextrose medium showed any toxicity or pathogenicity for the mice. Dr. Brown concludes that these strains cannot be converted to a pathogenic state for mice, under the conditions quoted in the paper by him and his colleagues.

Dr. Brown also points out that their paper does not claim to have "induced" strains of *B. cereus* to a pathogenic form. Rather, that in a given *B. cereus* population there may naturally exist a few cells which are pathogenic for mice and guinea pigs. The blood-dextrose environment selectively allows the more virulent forms to thrive and when these are passed via a large inoculum into appropriate animals, a pathogenic selection is made. On the basis of all available evidence this does not happen with *B. thuringiensis*. The techniques used by Brown

et al. are methods of selecting a pre-existing pathogen, not a method of "inducing" pathogenicity; if the pathogen is not naturally present one obtains results such as those that have been obtained with *B. thuringiensis*. At any rate, Brown's experiments indicate that those populations and strains of *B. thuringiensis* so far isolated and tested do not contain cells that are pathogenic for vertebrates. If such pathogen-containing populations or strains should appear in cultures used to prepare microbial insecticides, it is to be expected that they would be detected by the manufacturer before the product is released. In the laboratory, this could be accomplished by techniques for selectivity such as those used by Brown and his coworkers with *B. cereus*.

In conclusion, Brown states, "On a genetic basis it would be hard to conceive an insect pathogen being simultaneously pathogenic for vertebrates. It is highly improbable that even if a noncrystal-bearing variant is found that it would also be pathogenic for vertebrates as this would involve a great upheaval of the genetic mechanisms of the organism."

OTHER CONSIDERATIONS.—Other aspects of this entire matter should also be pointed out: *B. thuringiensis* has not been found to thrive or even be associated with vertebrates, even in a nonpathogenic state. Furthermore, occurring, as it does, in insects it is probably adapting itself to a habitat exceedingly different from that of the vertebrate body. The differences in body temperatures alone constitute habitat differences of great magnitude. Accordingly, it would probably be extraordinarily difficult, in even a deliberate attempt, to cause *B. thuringiensis* to grow well in a vertebrate animal. Even if such an attempt could succeed, it is not likely that a mutant pathogenic to a vertebrate host would become established. Moreover, the mechanism of pathogenicity of *B. thuringiensis*, involving the characteristic toxic crystal, appears to be distinctly different from that known to occur in the case of a pathogen such as *B. anthracis*. Also of importance is the fact that although bacterial pathogens of vertebrates have, of course, arisen during evolution, their origin is so infrequent as to have been largely unobserved. Similarly rare are the observed occasions when microörganisms, generally accepted as being nonpathogenic, have spontaneously become regularly pathogenic for a vertebrate. Moreover, although exceptions may occur, vertebrates are rarely suddenly attacked, through mutations to another species, by microörganisms regularly associated with them (such as in their intestinal tracts) as commensals. Although animals may ingest foliage treated with *B. thuringiensis* spores, there is no evidence that such contact will establish the bacterium in the animal's alimentary tract, or that such intimate contact is any more likely to result in infection than is the case with the commensals regularly harbored by the animal.

Instances in which a supposed strain of *B. cereus* has, upon passage through insects, been claimed to become crystalliferous and pathogenic for insects demonstrates only the genetic relationship between the two strains. It is well known that, in a given line, mutation to and from virulence may occur. But this is a wholly different matter from the type of phenomenon we have been discussing.

It should be made clear that what we have been saying pertains to pathogenicity as a manifestation of an infectious process. As with many materials, it is conceivable that microbial control products could provoke allergic reactions in a small minority of handlers, especially if handled carelessly. This possibility was pointed out in our previous paper. An example (unpublished) of a case of allergic response to an entomogenous microörganism (the fungus *Beauveria bassiana* (Bals.) Vuill.) has since been called to our attention by George T. York. Apparently a similar sensitivity has on occasion been noted by others. Of course, certain individuals are similarly sensitive to certain chemical insecticides. In all such cases, proper precautions should be taken by anyone making field applications or involved in excessive exposure to materials likely to provoke an allergic response.

As we have indicated previously (Steinhaus 1957), nothing in our treatment of this subject should be construed to mean that there should be any lessening in the vigilence with which manufacturers and others should produce, test, and standardize their "microbial insecticides." The phrase "anything can happen!" is as true in this area of activity as in any other. The same care exercised by manufacturers of other microbial products (dairy products, vaccines, fermentation products, et cetera) to avoid harmful contaminants and to check regularly for the emergence of variants and mutants of all kinds should be maintained. Moreover, circumstances surrounding the use of such products may change, giving rise to entirely new or "artificial" situations that may preclude the use of a given product— such as has been the case in the use of certain antibiotics that have allowed "harmless" microörganisms to act as pathogens. There are, of course, some dangers and pitfalls present in the manufacture and use of microbial insecticides just as in the manufacture of other microbial products. But the latter have, in general, proved to be safe and a great boon to mankind because they have been manufactured, distributed, and used under the safeguard of rigid, yet reasonable, controls and the maintenance of high standards. The same should be true for microbial insecticides, without there being undue fear of possible dangers that may be remote or that can be readily detected and controlled.

REFERENCES CITED

Brown, E. R., M. D. Moody, E. L. Treece, and C. W. Smith. 1958. Differential diagnosis of *Bacillus cereus*, *Bacillus anthracis*, and *Bacillus cereus* var. *mycoides*. Jour. Bact. **75**: 499–509.

Heimpel, A. M., and T. A. Angus. 1958. The taxonomy of insect pathogens related to *Bacillus cereus* Frankland and Frankland. Canadian Jour. Microbiol. **4**: 531–41.

Steinhaus, E. A., 1951. Possible use of *Bacillus thuringiensis* Berliner as aid in the biological control of the alfalfa caterpillar. Hilgardia **20**: 359–81.

Steinhaus, E. A. 1957. Concerning the harmlessness of insect pathogens and the standardization of microbial control products. Jour. Econ. Ent. **50**: 715–20.

Effects of Chemical Seed Treatments on Wireworm Activities[1,2]

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Abstract

Wireworms, *Melanotus* spp., were held in quart-size fruit jars containing moist soil and treated seeds to study the relative efficiencies of various insecticide seed treatments in killing them and protecting the seeds from their feeding.

The abilities of the insecticide treatments investigated to kill wireworms were ranked as follows: aldrin, good; heptachlor, fair; lindane and dieldrin, mediocre; endrin, poor.

Aldrin and lindane were the most repellent of these insecticides. The relatively greater repellency of aldrin, as compared with heptachlor or dieldrin, was attributed primarily to type two repellency. However the relatively high toxicity of aldrin made it first choice among the insecticides investigated, in spite of this repellency.

The relatively greater repellency of lindane, as compared with heptachlor or dieldrin, was attributed to a combination of two kinds of repellency (types one and two). This repellency appears to cause lindane to rank no higher than third among the insecticides investigated from the standpoint of potential usefulness as a corn seed treatment for controlling wireworms.

Heptachlor and dieldrin showed less type one repellency than lindane, and less type two repellency than aldrin or lindane. It was suggested that the inherent toxicity of heptachlor make it a better wireworm killer than dieldrin, and that this toxicity combined with lower degree of both type one and type two repellency make it a better wireworm killer than lindane.

Lilly (1953) noted a number of cases in which young field corn, growing from insecticide-treated seed under conditions of wireworm infestation, grew well during the first 2 or 3 weeks following planting, after which it suddenly wilted and stands were much reduced by wireworm injury. The literature indicates that BHC and lindane have received more attention as seed treatments for controlling wireworms than any other insecticides. Aldrin, dieldrin, and heptachlor all have shown definite promise. Limited trials with endrin by Kulash (1953, 1956) were not encouraging for this insecticide.

Long & Lilly (1958) called attention to the fact that there have been several suggestions from other investigators of a possible repellent action to wireworms from lindane and BHC. They concluded from their studies that aldrin, dieldrin, endrin, heptachlor, and lindane are repellent to wireworms in the following ways: (1) they tend to inhibit the feeding reaction (type one repellency); (2) they cause the insect to move away from the treated seed sooner than it otherwise would (type two repellency).

Lange *et al.* (1949) believed that the effectiveness of a seed treatment for wireworm control is dependent on: (1) the percentage of wireworms attracted to the seeds, and (2) the speed with which the insecticide acts. Thorpe *et al.* (1947) suggested that a wireworm bait should be mixed with a nonrepellent contact poison for maximum efficiency. We also agree with these conclusions, with one exception. Complete lack of repellency, as the term is defined above, is not necessarily a desirable quality in a seed treatment. Certainly a seed treatment should prevent injury to seeds, which is one aspect of type one repellency. The ideal seed treatment theoretically should inhibit the feeding reaction, but should not drive the insect away from the seed area, and thereby reduce its chances of contacting a lethal dose of poison.

This paper reports results from laboratory tests with aldrin, dieldrin, endrin, heptachlor, and lindane seed treatments for killing wireworms, and protecting seeds from wireworm damage. These results strengthen and extend the conclusions reached by the present writers in their earlier paper (1958).

Methods and Materials.—The wireworms used were described by Lane (1955) as belonging to the "*Melanotus communis* group" and "probably what Dietrich called *M. communis*, var B, in his New York Elateridae, Cornell Mem. 269, 1945." They were collected during the summer months from bait traps of spoiled shelled corn located in corn fields in North Central Iowa.

Chemicals were applied to the seeds in the manner described by Long & Lilly (1958). Aldrin, dieldrin, endrin, heptachlor, and lindane were applied at rates of $\frac{1}{2}$, 1, and 2 ounces of actual toxicant per bushel of seed. All seed lots were treated with a commercial powder containing 75% captan to give a dosage of one-half ounce of captan per bushel.

Dry powdered commercial formulations of each insecticide were compared with similar dosages of experimental formulations containing Carbowax 6000 or powdered vermiculite as diluents. The commercial formulations were wettable powders containing 75% of aldrin, dieldrin, heptachlor, and lindane, respectively, and 50% of endrin.

The experiment was factorial, involving 3 diluents, 5 insecticides and 3 rates of insecticide application. A total of 1,530 wireworms were used in 6 replications of 51 treatments, including the controls. Five wireworms and five seeds were confined together in each of 306 quart-size fruit jars containing moist soil for periods of 8 days, after which the seed and larvae were examined. Living insects were then returned to the jars with fresh soil and untreated corn as a source of food. After 13 additional days the larvae were again examined and the test terminated.

Results.—Counts of the numbers of dead plus moribund wireworms 13 days after exposure to treated seeds for an 8-day period, and of the numbers of seeds injured during the 8-day exposure period are summarized in table 1.

Aldrin and heptachlor were the most effective insec-

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[2] A portion of a dissertation submitted by the senior author to the Graduate Faculty of Iowa State College in partial fulfillment of the requirements for the Ph.D. degree.

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Table 1.—Average effects of treatment components summed over all others. Laboratory jar test, 1956.

TREATMENT COMPONENTS	WIREWORMS[a]	SEEDS[b]
Insecticides:		
Aldrin[c]	4.19	0.63
Dieldrin[c]	2.33	0.63
Endrin[c]	0.83	1.09
Heptachlor[c]	3.46	0.56
Lindane[c]	2.93	0.19
Controls[d]	0.42	3.83
Rates of applications:[e]		
0.5 oz. insecticide/bu.	2.47	0.78
1.0 oz. insecticide/bu.	2.71	0.53
2.0 oz. insecticide/bu.	3.07	0.54
Diluents:[e]		
Carbowax 6000	2.46	0.60
Commercial	2.90	0.53
Vermiculite	2.89	0.72

[a] Average numbers of dead plus moribund wireworms 13 days after the end of an 8-day period of exposure to insecticide-treated seed.
[b] Average numbers of seeds injured after 8 days of exposure to wireworms.
[c] These are averages from 54 jars containing 5 wireworms and 5 seeds each.
[d] This is an average from 36 jars containing 5 wireworms and 5 seeds each.
[e] These are averages from 90 jars containing 5 wireworms and 5 seeds each. Controls for insecticide treatments are not included.

ticides for killing wireworms under the conditions of this experiment. Lindane and dieldrin gave intermediate results, and endrin was practically ineffective. Aldrin was more effective than heptachlor, and lindane gave slightly better results than dieldrin.

The average effects of the three different rates of insecticide application indicate that wireworm kill increased consistently as the amount of insecticide applied increased from $\frac{1}{2}$ to 2 ounces per bushel of seed.

The average effects of the different diluents in the insecticide formulations indicate that the Carbowax 6000 formulation was slightly less effective than the powdered formulations in killing wireworms under the conditions of these experiments.

Analysis of variance of the average numbers of dead and moribund wireworms showed that there was a significant difference between the averages for insecticide treatments and controls at the 1% level of significance. Differences among insecticides and among rates of insecticide application were also significant at the 1% level. Differences among diluents were significant at the 5% level.

Observations of the conditions of these wireworms at the ends of their 8-day confinement with the treated seeds were also recorded, so that the increases in dead plus moribund insects during the intervals between the 8-day and 21-day readings could be calculated. The values found for the five-insecticides were as follows: aldrin, 55; heptachlor, 50; dieldrin, 42; endrin, 13; and lindane, −3 (a value of 54 would represent a 20% increase in kill of the total number of wireworms which were subjected to treatments containing a particular insecticide). The negative value for lindane indicates that three moribund larvae "recovered" during the 13-day interval following their confinement with treated seeds, or that the investigators' ability to differentiate between moribund and normal larvae was not infallible. In any case, it is apparent that lindane was the only insecticide tested which had exerted its full effect by the end of the 8-day exposure period.

All insecticide treatments gave considerable protection to the seed. Lindane-treated seeds were injured less than the others. Endrin-treated seeds were injured more than those receiving any other insecticide treatment, although less than one-third as many endrin-treated seeds were fed on as was the case with untreated seeds. Heptachlor-, aldrin-, and dieldrin-treated seeds were attacked by wireworms to extents intermediate between endrin-treated seeds on the one hand and lindane-treated seeds on the other.

Analysis of variance of the average numbers of seeds injured by wireworms in this experiment showed that there was a significant difference between the averages for insecticide treatments and controls at the 1% level of significance. Differences among insecticides were also significant at the 1% level.

DISCUSSION.—The primary objective of treating seed with an insecticide is to protect the seeds and young plants from insect attack. All of the treatments used reduced the tendency of wireworms to feed on treated seeds, but this reduction in feeding was not always proportional to the observed toxicity of the insecticide employed.

Aldrin and heptachlor gave good to fair wireworm kills with only 11 to 13% of the seeds being attacked. Dieldrin showed poorer kills and 13% of the seeds were attacked. Endrin gave very little kill, and about 22% of the treated seeds were attacked. These figures suggest that intensive feeding may not be necessary for wireworms to be poisoned. The results with endrin suggest that when the toxicity of a treatment is sufficiently low, more feeding on treated seeds can occur. On the other hand, since the endrin treatments were only slightly toxic, some other factor may be needed to help explain the fact that less than one-third as many of the endrin-treated seeds were attacked as were untreated control seeds. The different percentages of kill resulting from the aldrin, dieldrin, endrin, and heptachlor treatments respectively may reflect only the relative toxicities of these insecticides. However lindane gave kills intermediate between those of dieldrin and heptachlor, whereas only about 4% of the lindane-treated seeds were attacked, as compared with 11 to 13% of the other treated seed.

Although the hypothesis that toxicity alone is sufficient to explain the wireworm mortalities associated with the numbers of seeds attacked for the aldrin, dieldrin, endrin, and heptachlor treatments, respectively, may be accepted, it seems that something other than toxicity is needed to explain the relatively small amount of feeding on the lindane-treated seeds. Long & Lilly (1958) reported on the nature of the repellency to wireworms of the same seed treatments studied here. They found that type two repellency was most pronounced with lindane-treated seeds. The data presented above indicate that type one repellency is also most pronounced with lindane-treated seeds. Thus there is strong evidence that the extent and nature of the repellency of lindane-seed treatments, together with their toxicities, were important factors in determining the amount of wireworm injury suffered by lindane-treated seeds.

The results presented above show that lindane exerted its full effect more rapidly than aldrin, heptachlor or dieldrin. However aldrin and heptachlor exerted greater total effects than the other insecticides. Although the time required by aldrin and heptachlor to exert their full effects was relatively long, the total effect after almost any time interval following exposure of the insects to treated seeds would likely have equaled or surpassed that exerted by comparable lindane, dieldrin or endrin treatments.

The fact that heptachlor, in spite of being slightly below aldrin in toxicity, showed the good kills that it did may have been due to the failure of the larvae to move away from heptachlor-treated seeds as rapidly as they did from aldrin-treated seeds. Data of Long & Lilly (1958) indicate that this was true when not more than 1 ounce of aldrin was applied per bushel of seed.

The results presented above indicate that aldrin, dieldrin, and heptachlor possess about the same degree of type one repellency for wireworms under the conditions of these experiments. Long & Lilly (1958) concluded that a considerable amount of type two repellency was also characteristic of aldrin-treated seed when only ½ or 1 ounce was applied per bushel. Lindane was characterized by as much type two repellency as the medium or low dosages of aldrin (ibid.), and the results presented above indicate a greater amount of type one repellency from lindane than from any of the other insecticides investigated.

CONCLUSIONS.—These studies suggest a need for further experimentation under field conditions. The following tentative conclusions are based on the extensive laboratory experiments summarized above:

(1) The ability of the insecticide treatments investigated to kill wireworms may be ranked as follows: aldrin, good; heptachlor, fair; lindane and dieldrin, mediocre; and endrin, poor.

(2) Aldrin and lindane were the most repellent of the insecticides investigated.

(3) The relatively greater repellency of aldrin, as compared with heptachlor or dieldrin, is attributed primarily to type two repellency. However the relatively high inherent toxicity of aldrin appears to make it first choice among the insecticides investigated, in spite of this repellency.

(4) The relatively greater repellency of lindane, as compared with heptachlor or dieldrin, is attributed to a combination of both kinds of repellency (types one and two). This repellency caused lindane to rank no higher than third among the insecticides investigated from the standpoint of potential usefulness as a corn-seed treatment for controlling wireworms.

(5) Heptachlor and dieldrin showed less type one repellency than lindane, and less type two repellency than aldrin or lindane. It appears that the inherent toxicity of heptachlor makes it a better wireworm killer than dieldrin, and that this toxicity, combined with lower degrees of both type one and type two repellency, makes it a better wireworm killer than lindane.

(6) Treatments of aldrin or heptachlor applied at the rate of 2 ounces of actual insecticide per bushel of seed should result in more satisfactory wireworm control than has generally been reported in the past for seed treatments on corn.

REFERENCES CITED

Kulash, W. M. 1953. Insecticidally treated seed for wireworm control. Jour. Econ. Ent. **46**: 433–41.

Kulash, W. M. 1956. Further laboratory tests for wireworm control. Jour. Econ. Ent. **49**: 65–67.

Lane, M. C. Walla Walla, Washington. 1955. Private communication.

Lange, W. H., Jr., E. C. Carlson, and L. D. Leach. 1949. Seed treatments for wireworm control with particular reference to the use of lindane. Jour. Econ. Ent. **42**: 942–55.

Lilly, J. H. 1953. Treatments for soil insects. Proc. Eighth Annual Hybrid Corn Industry-research Conf. **8**: 76–92.

Long, W. H., and J. H. Lilly. 1958. Wireworm behaviour in response to chemical seed treatments. Jour. Econ. Ent. **51**: 291–5.

Thorpe, W. H., A. C. Crombie, R. Hill, and J. H. Darrah. 1947. The behaviour of wireworms in response to chemical stimulation. **Jour. Exptl. Biol. 23**: 234–66.

BOOK REVIEW

"HANNA'S HANDBOOK OF AGRICULTURAL CHEMICALS," Second Edition, by LESTER W. HANNA. 493 pp., illus. Published by Lester W. Hanna, Forest Grove, Ore., 1958. Price $5.95. In lots of 50 or more copies, $3.75 each.

While this handbook contains much information that might be useful to the farmer and others concerned with the use of agricultural chemicals, it is not at all discriminating as to content and organization. Chemicals that have undergone only preliminary screening tests are included along with materials that are in everyday use. There is little consistency in the way that compounds are listed, some appearing under their chemical names, some under trade names, and others under both. As an example of the lack of organization, Chapter 13, Livestock Chemicals, is largely made up of items such as Animal Game Hunting-Safety Rules, Artificial Insemination, Bloat, Dairy Product Flavors, Egg Shell Mottling, Heart Disease, Livestock Shades, Vibrosis Aborting, which make no reference to chemicals. Some of the information included is rather intriguing, but of doubtful utility to the readers it will reach; *e.g.*, treatment of penguins in zoos against aspergillus fungus, the UKACO method of electronic insect control, and water witching.

The book does bring together a considerable number of useful items, such as the summary of official residue tolerances published in the National Agricultural Chemicals Association (NACA) News, the spray compatibility chart from the American Fruit Grower, safety rules for handling pesticides from the NACA News and from National Safety Council publications, and descriptions of many pesticidal chemicals apparently excerpted from government bulletins, company literature, journal articles, etc. Unfortunately these pieces of information are scattered through a heterogeneous mixture that makes it difficult to use the book.

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Texas Field Tests for the Control of Cattle Grubs with Sprays of Bayer 21/199[1]

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Abstract

Single or multiple treatments with sprays of Bayer 21/199 (*O*-(3-chloro-4-methylumbelliferone) *O,O*-diethyl phosphorothioate) were used in field tests on ranches near Kerrville and Spur, Texas, for the systemic control of cattle grubs. At Kerrville five treatments with 0.75% spray completely prevented encystment of grubs. A single treatment with 0.5% spray prevented all but one grub from reaching the backs of treated animals. However, one treatment with 0.25% spray afforded only 53% control. At Spur groups of cattle were sprayed once with 0.5% 21/199. This treatment resulted in 90 to 96% control of grubs. Benefits derived from grub control and reasons for failure of 0.25% spray are discussed.

Spray treatments with Bayer 21/199 (*O*-(3-chloro-4-methylumbelliferone) *O,O*-diethyl phosphorothioate) made prior to encystment of common cattle grubs, *Hypoderma lineatum* (De Vill.), have prevented the first-instar larvae from appearing in the backs of cattle. Brundrett *et al.* (1957) found that one spraying with 0.75% 21/199 caused almost 100% reduction in numbers of warbles. Graham (1958), in another test with larger numbers of cattle infested with *H. lineatum* and *bovis* (L.), found that concentrations of 0.25, 0.5, and 0.75% were almost equally effective in preventing the encystment of grubs when extreme care was taken to insure wetting of the skin by applying large quantities of the insecticide at high pressure with the nozzle close to the animals' bodies. Since both tests were conducted under carefully controlled conditions, it was necessary to see if results could be duplicated under a wide variety of field conditions. Tests with this compound on two ranches near Kerrville, and three ranches near Spur, Texas,[2] are reported herein.

Tests at Kerrville.—Two herds of registered Hereford cows and heifers, maintained by the owners in accordance with usual ranch practices, were each divided into groups, and the groups were marked with a special cattle-marking dye. Since both herds were part of a program to test sprays for the control of the lone star tick, *Amblyomma americanum* (L.), the control animals were sprayed with materials that would control ticks but not affect the grubs. The insecticides were applied with a power sprayer at a pressure of 250 pounds per square inch.

Herd 1 consisted of 54 animals and was divided into two groups for a test of repeated spray applications. Thirty animals were sprayed with Bayer 21/199 at a 0.75% concentration, and the remaining 24 with lindane at 0.05%. Both groups were sprayed with 1 to 2 gallons per animal five times from February 7 through July 21, 1957. For the first three sprayings a wettable powder (50%) was used, and for the last two sprayings a wettable powder (25%). The lindane spray was made from a wettable powder (25%).

Herd 2 consisted of 53 animals and was divided into three groups for a test of single spray treatments. The first group of 21 cattle was sprayed with 0.5% Bayer 21/199, the second group of 20 with 0.25% Bayer 21/199, and the remaining 12 with 0.5% toxaphene. The animals in each group were sprayed with approximately 1½ gallons per head on June 7, 1957. The 21/199 spray was from a wettable powder (25%) and the toxaphene from an emulsifiable concentrate (50%).

Several animals were lost from each group because of sales and inability to read faded dye marks. At the completion of the experiments there were 45 animals in test in herd 1 and 43 in herd 2. The herds were checked for grub encystment at monthly intervals from August through December. To obtain a cumulative count of the total number of grubs in each animal, the location of each grub as it appeared in the animal's back was recorded on an outline map.

The results of the tests at Kerrville are summarized in table 1. No grubs were found in the backs of the cattle treated with 0.75% Bayer 21/199. One cow receiving the 0.5% spray had a single grub in its back. The 0.25% treatment did reduce the number of grubs that encysted by 53%. A "t" test was used to determine the significance of this reduction, and the difference in average number of grubs between treated and untreated animals was not significant at the 5% level.

Tests at Spur.—All the animals were Hereford cows or yearlings. At each of three ranches a certain group was selected for one treatment with a 0.5% spray of Bayer 21/199 made from a wettable powder (25%). All the animals treated, except for a feed lot group, were maintained on pasture according to local range practices. On July 17, 1957, the spray was applied with a power sprayer at a pressure of 250 pounds per square inch, at the rate of approximately 1 gallon per head. This quantity was enough to wet most of the animals; however, those in herd 3 were not well saturated. No attempts were made to drive the insecticide into the hair or decrease amounts of runoff.

In herd 1, two groups of cattle were treated. The first group consisted of 16 heifers which were being put into a feed-lot. Fourteen steers, which were also being put into the same feeding operation, were designated as controls. The second group consisted of 14 cows from a large herd. All the animals were horn-branded and numbers of the treated cattle were recorded.

In herd 2, 44 cows were sprayed. These animals were also horn-branded. Untreated animals were maintained in a pasture adjoining the field which contained the treated animals.

In herd 3, 10 cows were sprayed. These animals were part of a large herd maintained in a single pasture.

The numbers of grubs in the backs of cattle were counted twice during the season of grub emergence. The dates of examination, December 11, 1957, and January

[1] Accepted for publication December 8, 1958.

[2] P. T. Marion, superintendent of the Texas Agricultural Experiment Substation No. 7, arranged for and accompanied the author on the work around Spur.

Table 1.—Total numbers of cattle grubs in backs of cattle treated with sprays of Bayer 21/199 from two ranches near Kerrville, Texas.

PER CENT OF 21/199	NUMBER OF SPRAYINGS	NUMBER OF ANIMALS		NUMBER OF GRUBS		
		In Test	Infested	Total	Range	Average
		Herd 1				
0.75	5	26	0	0	0	0.0
None		19	13	176	0–27	9.2
		Herd 2				
0.5	1	17	1	1	0–1	0.06
0.25	1	16	12	85	0–18	5.3
None		10	10	114	1–36	11.4

22, 1958, were 42 days apart so that most of the grubs counted at the earlier date would not be present at the later one. No attempt was made to obtain cumulative counts on the numbers of grubs appearing in each animal. The amount of control afforded by the sprays was determined by the difference in average number of grubs between the treated and untreated animals.

At the time the examinations for encystment of grubs were made, the treated cows in herd 1 were calving and only a few were available. Data from both checks are combined into a single count. The heifers and steers in the feed lot were slaughtered soon after the first examination. Thirty-two of the 44 cows treated in herd 2 were checked both times. Herd 3 was moved to distant pastures after the first examination and was not available for the second.

Reduction in average number of warbles per head varied from ranch to ranch, but was at least 90% at all ranches. The results of the tests at Spur are summarized in table 2.

DISCUSSION.—The results obtained from these tests were in general agreement with the earlier results obtained by Brundrett *et al.* (1957) and Graham (1958). In Kerrville the single spraying of 0.5% and the repeated spraying of 0.75% were both almost 100% effective in preventing grub encystment, but the single application of 0.25% spray failed to give complete control. At Spur control with the 0.5% spray was less than that obtained by Graham (1958).

In both the earlier tests special care was taken to insure adequate wetting of the animals' skin. Also animals were sprayed so that large amounts of the insecticide would remain on the hair or in contact with the skin. In these tests the animals at Kerrville were sprayed so as to insure adequate coverage for tick control and those at Spur until they appeared to be thoroughly wetted. No special measures were taken to decrease the amount of runoff or to drive the spray through the hair and onto the skin. Since the animals in both areas were in short summer hair, the insecticide appeared to reach the skin.

The profit to the rancher afforded by grub control was

Table 2.—Cattle grubs in backs of cattle treated with sprays of 0.5% Bayer 21/199 from three ranches near Spur, Texas.

	NUMBER OF ANIMALS		NUMBER OF GRUBS			PER CENT CONTROL
	In Test	Infested	Total	Range	Average	
Herd 1						
Examined Dec. 11 and Jan. 22, data combined						
Treated	8	4	6	0–2	0.75	90
Untreated	59	52	431	0–36	7.3	
Feed-lot animals, examined Dec. 11						
Treated	16	2	8	0–7	0.5	96
Untreated	14	14	231	2–31	16.5	
Herd 2						
Examined Dec. 11						
Treated	32	8	15	0–4	0.5	95
Untreated	24	24	219	1–34	9.1	
Examined Jan. 22						
Treated	32	9	16	0–3	0.5	93
Untreated	20	20	150	1–16	7.5	
Herd 3						
Examined Dec. 11						
Treated	10	9	19	0–3	1.5	91
Untreated	15	15	290	5–37	19.3	

demonstrated at Spur. The feed-lot cattle, of which heifers were treated and steers were untreated, were marketed during the season of grub emergence. The animals were on the same ration and the steers were approximately 200 pounds heavier than the heifers. At the stockyards the buyers examined the cattle, and because the heifers were practically grub free, the price was $2.00 per cwt. higher than that paid for the steers. Since steers ordinarily bring $2.00 per cwt. more than heifers, it was calculated that the treated animals sold for approximately $12.00 per animal more than they would have had they not been treated.

Owners of these cattle did not notice any symptoms of toxicity in their cattle that were sprayed with Bayer 21/199. However, data on toxicology of this insecticide recently obtained by Radeleff (unpublished data) may eliminate the general use of concentrations above 0.5%.

It seems that Bayer 21/199 used as a spray could be considered a practical treatment before the grubs damage meat and hides of cattle. However, further research is needed to determine amounts of spray, methods of application, concentrations of insecticide, timing, and numbers of applications necessary to insure complete control.

REFERENCES CITED

Brundrett, H. M., W. S. McGregor, and R. C. Bushland. 1957. Systemic cattle grub control with Bayer 21/199 sprays. Agric. Chemicals 12(6): 36–7, 123, 125.

Graham, Owen H. 1958. Tests with Bayer 21/199 for the control of cattle grubs. Jour. Econ. Ent. 51(3): 359–60.

Grain Storage Fungi Associated with Mites[1]

D. A. Griffiths,[2] A. C. Hodson,[3] and C. M. Christensen[4]

Abstract

Grain-infesting mites *Acarus siro* and *Tyrophagus castellanii* were found in some abundance in samples of commercially stored wheat, the moisture content of which ranged from 13.5 to 15%, which is the range of moisture content at which fungi in the *Aspergillus glaucus* group are likely to predominate. These mites, when developing in moldy grain, picked up spores of the storage fungi and carried these spores on the outside of their bodies, in their digestive tract, and in their feces. As they entered clean grain they inoculated it heavily with spores of these fungi, and later they fed to a considerable extent upon the fungi that developed. They preferred certain fungi to others, and preferred those members of the *A. glaucus* group, such as *A. amstelodami*, *A. repens*, and *A. ruber*, which thrive in grain of which the moisture content ranges from 13–15%, to *A. candidus*, *A. ochraceus*, and *A. flavus*, which require a higher moisture content. The mites not only sought out the preferred fungi, when given a free choice, but also digested a considerably greater percentage of spores of these fungi than they did of the nonpreferred fungi, which seems a sound biological basis for preference. It is likely that whenever heavy infestations of these mites are found in grain, there will be damage not only from mites feeding on the embryos of the kernels, but also from the storage fungi that accompany them.

The literature contains conflicting statements as to the relationship between mites and fungi in stored products. Hase (from Solomon 1946) maintained that *Acarus siro* L. did not eat molds, but secreted a substance which inhibited fungus development. Andre (1939) considered that the Tyroglyphid mites are primarily feeders on fungi, and that *A. siro* is found most abundantly and frequently in stored materials in which fungi are developing. Rodionov (1940) stated that infestations by mites usually are accompanied by a considerable development of microörganisms, especially fungi, which the mites disseminate, while Solomon (1946) reported that in small tubes of grain at fairly high humidities mites often hindered the growth of molds by feeding on them. All these workers evaluated the amount of fungus material present only by visual examination.

In numerous samples of wheat obtained from commercial bins by the writers, mites were found to be developing vigorously, especially in grain of which the moisture content ranged from 13.5 to 15%. At this moisture content certain storage fungi that contribute to deterioration are known to thrive (Christensen 1955), and Agrawal *et al.* (1957) found that granary weevils developing in grain at this moisuture content greatly increased the abundance of certain of the storage fungi. It seemed desirable to determine whether mites also were associated with these fungi.

Materials and Methods.—Two species of mites, *Acarus siro* L., 1758 (= *Tyroglyphus farinae* L.) and *Tyrophagus castellanii* Hirst, 1912 (= *Tyroglyphus longior* var. *castellanii* Hirst) were obtained from samples of wheat sent in from commercial bulks stored in various parts of the United States.

Moisture contents were determined by the two-stage, air-oven method specified by Cereal Laboratory Methods (Amer. Assoc. of Cereal Chemists 1957) and are expressed on a wet weight basis.

Number of kinds of fungi present were determined by two methods: 1) One hundred seeds were washed in 1% sodium hypochlorite for 1 minute, rinsed in two changes of sterile distilled water, cultured on malt-salt agar (2% agar, 2% Difco powdered malt extract, 7.5% sodium chloride), and incubated at room temperature until the fungi that grew from the seeds could be identified. 2) Five gm. of grain were suspended in 500 ml. of sterile 0.15% agar solution in a Waring Blendor, comminuted for 1.5 minutes, 5 ml. removed and placed in 45 ml. of the same suspension medium, shaken (additional dilutions, where necessary, were made by the same procedure), 1-ml. portions of one or more suspensions placed in replicate sterile petri dishes, malt-salt agar cooled to 52° C. added, the dishes swirled to distribute the suspended materials uniformly, and the dishes incubated at room temperature until the colonies could be counted and identified. Both of these procedures are more or less standard in evaluating number and kinds of fungi present in stored grains and similar materials.

Additional procedures are described in the accounts of individual experiments given below.

Results.—*Development of Fungi in Wheat Stored at 17% Moisture Content, With and Without Mites.*—Hard red spring wheat of certified seed grade and known to be almost free of storage fungi, was adjusted to 17% moisture content and 50 gm. placed in each of 15 sterile wide-mouth bottles. The bottles were closed with sterile stoppers equipped with ventilating tubes, and the outer end of the tubes covered with fine taffeta to prevent escape of mites. Each of five bottles was inoculated with 1,000 adult *T. castellanii*, each of another set of five with 1,000 *A. siro*, and the remaining set of five left uninoculated, as controls. The bottles were placed in a desiccator ventilated with air bubbled through a saturated solution of ammonium sulphate to maintain a relative humidity of 80%, in equilibrium with a moisture content in the grain of 17%. After 8, 22, and 36 days one bottle of each set was removed, the number of mites counted, and the grain tested for moisture content and mold count. The results are given in table 1.

After 8 days, the number of surface disinfected kernels that yielded various storage fungi was about three times as great in the grain where *Acarus siro* was present, and seven times as great where *T. castellanii* was present, as in the controls. The number of colonies of *Aspergillus glaucus* increased rapidly with time in the controls, less rapidly in the grain containing *Acarus siro*, and slowly in the grain containing *T. castellanii*. Where the mites

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Table 1.—Influence of mites upon development of fungi in wheat stored 36 days at 17% moisture content.

Test Period (days)	*Aspergillus* Colonies per Gm. of Grain (thousands)			Per Cent of Surface-Disinfected Seeds Yielding *Aspergillus*	Moisture Content of Grain (%)	Number of Mites (hundreds)
	glaucus	*restrictus*	*candidus*			
	Inoculated with *Tyrophagus castellanii*					
8	0.3	0.5	0.1	70	17.0	2.4
22	500	1,875	540	100	17.0	66.0
36	280	3,100	8,500	100	16.8	64.2
	Inoculated with *Acarus siro*					
8	0.4	3	0.2	28	17.2	3.0
22	3,810	500	3,500	100	17.2	18
36	575	50	13,000	100	16.8	67.5
	No mites					
8	0.1	2	0.1	10	17.3	0
22	5,000	0	12,750	100	17.2	0
36	11,620	250	68,500	100	16.8	0

were present the count of *Aspergillus glaucus* decreased greatly between 22nd and 36th day. The count of *A. candidus* increased with time in all three cases, but less rapidly where mites were present than in the controls. The count of *A. restrictus*, however, increased consistently, and the final count was much higher, in the grain infested with *T. castellanii*, than in the controls. This may have been due to *T. castellanii* consuming the other fungi and allowing *A. restrictus* to sporulate, or to the mites having introduced a heavier inoculum of this fungus than was introduced into the controls by chance contamination. Sporophores of *Aspergillus spp.* growing from the germs of the grains were much more numerous in the controls than where mites were present, presumably because the mites grazed off many of the sporophores.

Damage to Grain by T. castellanii.—In several tests *T. castellanii* was allowed to develop for some weeks on wheat held at moisture contents of 14 to 16%. In all cases the mites rapidly invaded the germs of those seeds which had breaks in the pericarp over the germ; they did not enter the germs of seed which had sound pericarps. Eventually they consumed the entire germ of those seeds which they were able to enter, and sometimes burrowed a short distance into the endosperm adjacent to the germ. When mites were absent at the time of examination their former presence in the damaged germ could be ascertained by the great numbers of fecal pellets in the cavity. The same sort of damage was found in samples of grain from commercial bins, when these harbored large populations of *T. castellanii*. Such damage has not previously been reported to be caused by this mite.

Passage of Viable Spores of Storage Fungi Through the Digestive Tract of Mites.—In preliminary tests, mites from moldy grain were transferred to autoclaved wheat kept at a moisture content of 17 to 18%. After 6 to 7 weeks kernels were surface-disinfected and cultured on malt-salt agar: 100% of these yielded storage fungi, including eight species of *Aspergillus* and one of *Penicillium*, while the controls yielded no fungi. It seemed of interest to determine whether the mites would transmit such inoculum internally.

Adults of *T. castellanii* and *Acarus siro* were placed on pure cultures of various storage fungi growing on malt-salt agar in petri dishes, and left for 72 hours, during which time they were observed to feed on the fungi.

Table 2.—Number of fungus spores in fecal pellets of mites feeding on these fungi, and percentage of these spores germinating.

Mite	Food Fungus	Number of Spores[a] per Fecal Pellet	Germination of Spores	
			In Fecal Pellets (%)	From Fungus on Grain (%)
T. castellanii	*Aspergillus repens*	349	4.6	96.5
	A. amstelodami	371	3.4	97
	Penicillium sp.	703	85.4	98
Acarus siro	*A. repens*	272	45	95
	A. restrictus	457	77.4	97

[a] Each figure represents average number from 5 to 10 boluses.

Mites were then removed, washed in 1% sodium hypochlorite, and killed by a brief submersion in carbon tetrachloride (this did not appear to injure the fungi). Each of approximately 100 mites was then placed on a flat drop of malt-salt agar on the under side of a cover slip, and this placed on a van Tiegham cell in a petri dish, and observed periodically with the microscope. No fungi grew from the outside of these surface-disinfected mites, but within 48 hours mycelium grew out from nearly all of them. Mycelium grew from the mouth, the anal and genital openings, and down the interior of the legs and out the tip of the tarsus, as shown in figure 1.

This indicated that viable inoculum of the various fungi on which the mites had been feeding was present within the body of the mite, but did not show whether viable spores might be voided in the excreta. To determine this, surface-disinfected mites were dissected, under 30× magnification, the midgut and anal boluses removed, examined microscopically and cultured on hanging drops of malt-salt agar. When the mites had been feeding on either moldy grain or fungus cultures, fungus spores made up a considerable portion of both boluses. Boluses taken from mites living on eight different species of *Aspergillus* and one species of *Penicillium* yielded cultures of the food fungus in every case.

Pure cultures of several species of common storage fungi were grown on autoclaved grain at approximately 18% moisture content. After the fungi had sporulated mites were added, each species of mite being added separately to grain containing a single fungus. Three days later, fecal pellets were collected from the grain, placed on a thin agar droplet on a slide, squashed lightly under a small piece of sterile polyethylene film, and the slide incubated in a moist, sterile petri dish. The number of spores per pellet, and the percentage of spores germinating, are given in table 2.

With a given species of mite on grain with one species of fungus, the percentage of germinating spores in the fecal pellet was relatively constant, but there were considerable differences between the two mites feeding on a single species of fungus, and among different fungi eaten by one species of mite. Only 4.6% of the spores of *A. repens* in the fecal pellets of *T. castellanii* germinated, while in the pellets of *Acarus siro* 45% of the spores of this fungus germinated. Spores of this fungus taken from grain but not passed through the mite consistently germinated from 94 to 98%. On the other hand, 86% of the

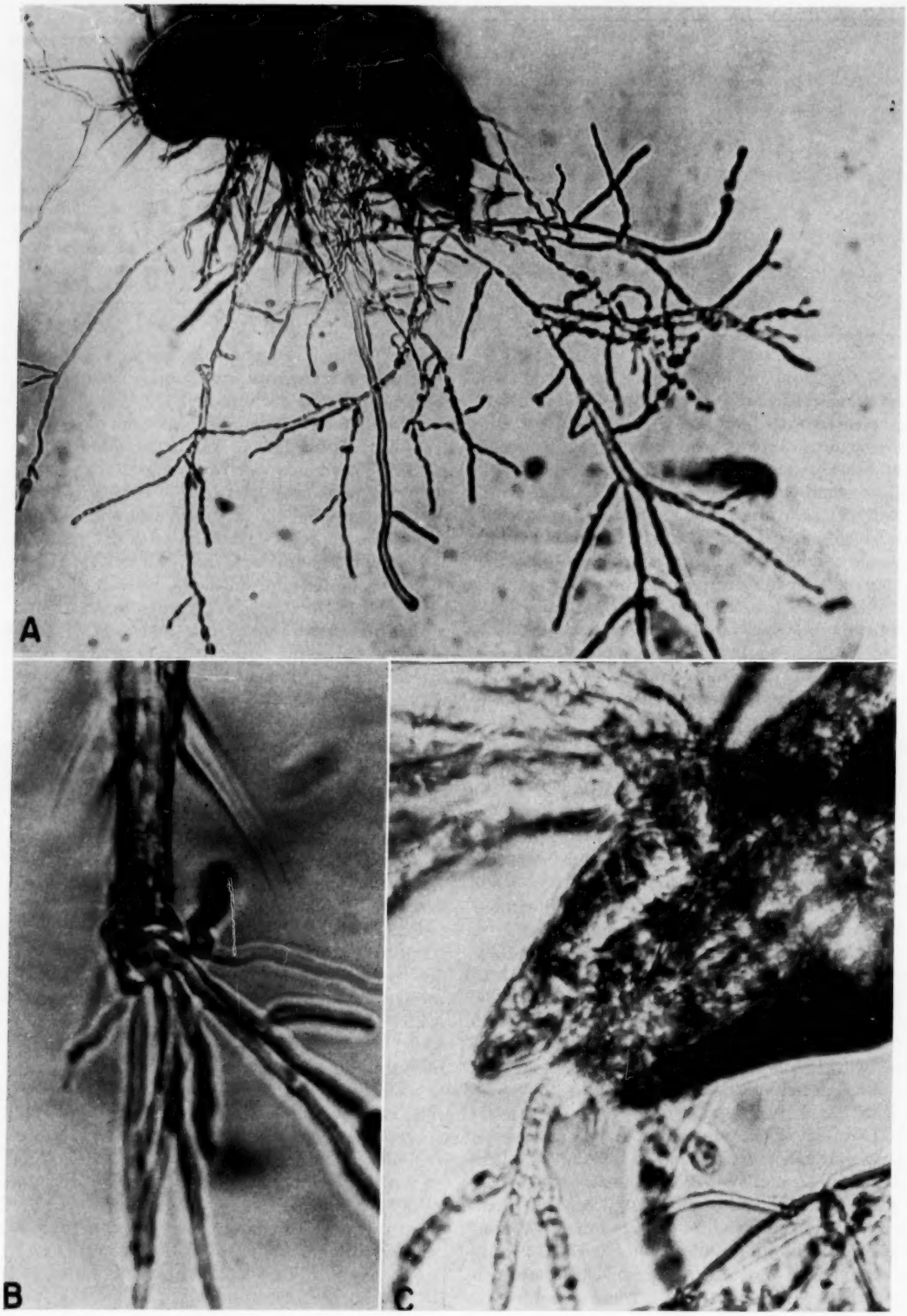

FIG. 1.—Fungi growing from the interior of surface-disinfected mites. A. From the genital opening. B. From the end of a tarsus. C. From the mouth.

spores of *Penicillium* in the pellets of *T. castellanii* germinated, and 78% of the spores of *A. restrictus* in the pellets of *Acarus siro* germinated. Evidently a given species of mite may digest a much greater proportion of the spores of one fungus it eats than of another. All the pellets tested contained a sufficient number of viable spores of whatever fungus was eaten, to furnish abundant inoculum of that fungus. There seems little doubt that as these mites wander through grain or other stored materials they continually eat and disseminate viable spores of storage fungi.

Preference of T. castellanii for Certain Storage Fungi.—A considerable number of tests were made to find out whether certain fungi were more attractive than others to this mite, and the results will be summarized briefly. Pure cultures of the fungi were grown on malt-salt agar, then squares approximately 1 cm. across of agar plus fungus were cut from each culture with a flamed scalpel, placed in a sterile petri dish, just in from the margin, leaving the center of the dish free. The order of placement was varied from dish to dish. Mites free of food particles were brushed into the center of the dish, the dish covered and sealed, and placed in a desiccator in which a relative humidity of 75% was maintained by means of a saturated solution of sodium chloride. The desiccators were covered to exclude light, and were periodically rotated. At intervals of 12 hours up to 100 hours the mites on each square of fungus were counted.

In all of these tests, judging by the number of mites present on a given square of fungus, *Aspergillus repens* was far more attractive to *T. castellanii* than any of the other 10 species of fungi tested. In one test, for example, 510 mites visited and fed on the square of *A. repens*, and 240 were found on *A. ruber*, while only a few were observed on *A. candidus*, *A. flavus*, *A. ochraceus*, or *A. restrictus*. Spores of *A. repens*, as noted in a previous paragraph, were less viable than others tested after passing through the mite digestive tract.

Table 3.—Number of living mites (*T. castellanii*) on adjacent squares of most-preferred and least-preferred fungi after 1.5 to 72 hours.

Aspergillus Species	Number of Mites after Hours Shown			
	1.5	24	48	72
repens	66	63	91	74
candidus	35	12	10	6
amstelodami	53	68	83	24
candidus	24	4	3	3
repens	38	64	73	76
ochraceus	19	11	10	7
amstelodami	57	87	88	34
ochraceus	34	6	7	17
repens	55	64	86	98
repens	59	68	77	81
amstelodami	57	82	93	69
amstelodami	61	76	89	52
Sterile agar alone	80	11	4	6
Sterile glass square	6	4	7	4

To compare relative attractiveness of fungi near the top of the preference list with those toward the bottom, squares of two fungi were placed adjacent to each other in the center of a dish, and approximately 100 mites were added near the edge of the dish, after which the dish was covered and the mites on each fungus square were counted periodically. Squares of malt-salt agar without fungus, and squares of glass served as controls. Typical results are given in table 3.

Given free choice in these tests, from 7 to 25 times as many mites were found on the squares of *A. repens* and *A. amstelodami*, within 48 hours, as were found on

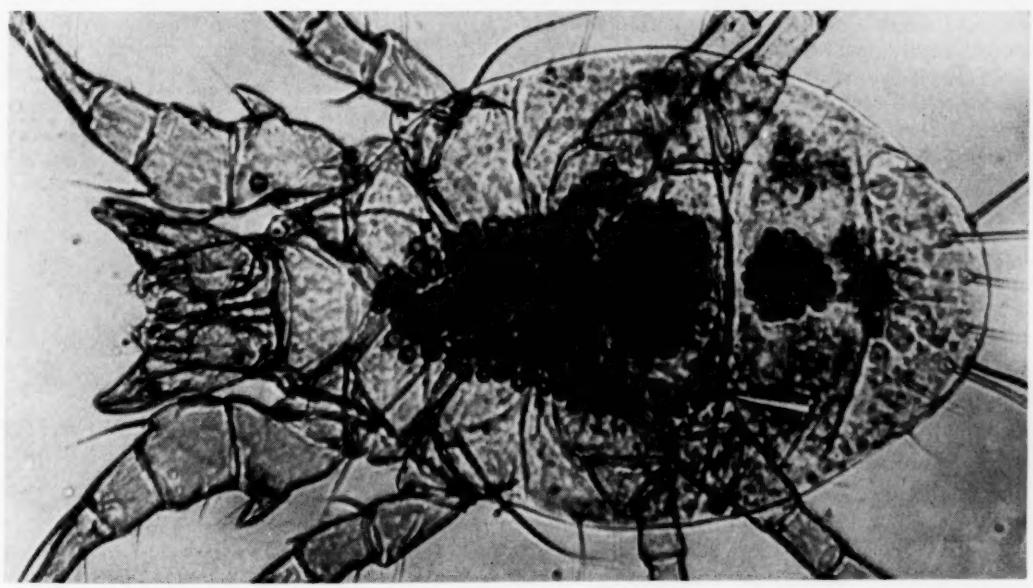

FIG. 2.—Corn smut spores in the digestive tract of a mite. The spores extend down almost to the tip of one caecum (arrow); the midgut and anal boluses are very evident.

adjacent squares of *A. candidus* or *A. ochraceus*. Where sterile agar alone was used, nearly all the mites were found on it within 30 minutes, but after 48 hours few mites were present; presumably the mites were first attracted to the agar by the moisture, but left when no food attractive to them was found. Only a few mites were observed on the glass square. Evidently the adults of *T. castellanii* have a very decided preference for *A. repens* and *A. amstelodami*, and a sense which enables them to select these in preference to unattractive fungi such as *A. candidus* and *A. ochraceus*.

Nature of the Behavioral Response.—When it was discovered that *T. castellanii* is attracted to some stored fungi more than others tests were devised to determine the kind of behavioral response. A piece of paper marked in ¼-inch numbered squares was fitted to a 9-cm. petri dish. Small pieces of sterile agar or agar bearing a heavy fungus growth were placed on a square near one edge of the dish, a mite put on a starting point 7 cm. away, and the dish covered. The path of the mite was traced on tracing paper laid over a larger circular piece of paper marked with ¾-inch squares which were given numbers corresponding to those on the test paper. Mites to be tested were fed red-dyed wheat germ so that they could be seen more easily.

The mite behavior was of two types: first, a klinokinetic response while they were some distance from the bait, then a marked klino-taxic response as they moved closer. The response to both sterile and fungus-bearing agar was positive in a dry atmosphere, presumably because the mites were responding to a humidity gradient set up by the moist pieces of agar. When wet agar, both sterile and fungus bearing, were set up in a nearly saturated atmosphere the mites showed no response to the presence of sterile agar, but a very striking klino-taxic response to the fungus bearing pieces.

THE FEEDING PROCESS.—The feeding of many individuals of both *T. castellanii* and *Acarus siro*, principally on cultures of *Aspergillus repens*, was followed in some detail, and since the process had not been described it seems worth recording.

Both used the chelicera to cut down conidiophores and to pull them into the mouth. Sometimes the front pair of legs were raised, moved forward, and raked back through the fungus, bringing material within reach of the mouth parts. When the mites were feeding vigorously, an almost continuous stream of spores passed down the esophagus to the foregut, where it appeared to be suspended in a liquid. The food, mainly spores, filled the midgut and extended down into the caeca; it was rhythmically churned, forced alternately into the right and left caecum, and filled each caecum almost to the distal end as shown in figure 2. As soon as the foregut was filled with food, the anal bolus was ejected as a fecal pellet, the bolus within the midgut moved through the now opened sphincter muscle into the rectal chamber. The caecal movement then became more rapid and vigorous for a short time, but soon ceased. The food within the foregut chamber became compressed in the posterior half of the chamber, where it was molded into a loose ball, the sphincter muscle opened and the bolus was pushed into the midgut, after which the sphincter muscles closed and the caecal movement again began. The entire process, from ingestion of the spores to deposition of these spores as a fecal pellet, required about 10 to 12 minutes. The spores, therefore, were exposed to the digestive process for 10 to 11 minutes at most, and the spores ingested just before the prebolus was formed presumably were exposed even a shorter time. That more than 90% of the spores of some species of *Aspergillus* are killed in this time (table 2) indicates that these mites may have some rather potent digestive juices.

REFERENCES CITED

Agrawal, N. S., C. M. Christensen, and A. C. Hodson. 1957. Grain storage fungi associated with the granary weevil. Jour. Econ. Ent. **50**: 659–63.

American Association of Cereal Chemists. 1957. Cereal laboratory methods. Ed. VI. Published by the Association.

Andre, M. 1939. Notes sur les acariens observes dans les magasins regionaux de tabac. Ann. Epiphyt. 19(6): 331–56.

Christensen, C. M. 1955. Grain storage studies XVIII. Mold invasion of wheat stored for sixteen months at moisture contents below 15 per cent. Cereal Chem. **32**: 107–16.

Rodionov, Z. S. 1940. The qualitative and quantitative damage caused by grain mites. Uchen. Zap. mosk. gosud. Univ. no. (**42**) Zool. 141–65. (In Russian, abstr. in RAE 31A:70.)

Solomon, M. E. 1946. Tyroglyphid mites in stored products. Nature and amount of damage to wheat. Ann. Appl. Biol. **33**: 280–98.

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Laboratory Studies of the Seasonal Tolerance of the Potato Flea Beetle to DDT[1]

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Abstract

During the period of 1954–58, field and laboratory studies of the erratic control of the potato flea beetle, *Epitrix cucumeris* (Harris), with DDT was shown to be a matter of vigor tolerance rather than resistance. With one generation of the insect present annually, overwintered beetles were found to succumb readily to small deposits of DDT in June and early July, while the new generation appearing in mid-July became progressively more tolerant of the insecticide as the season advanced. Less extensive investigations of dieldrin showed results similar to those of DDT, except that the insecticide was effective at levels considerably lower than DDT.

The erratic results observed by many Rhode Island potato growers with DDT for control of the potato flea beetle, *Epitrix cucumeris* (Harris), particularly since the early 1950's, has led to the assumption that the insect has developed resistance to the insecticide. Comment has centered principally on the observation that control of the insect was relatively satisfactory early in the potato-growing season but tended to become less satisfactory later. Resolution of the problem was attempted under field conditions during the period 1954–56, inclusive, but because of inability to regulate insecticide deposits and fluctuating mobile beetle populations no definite conclusions could be made. In 1957 and 1958 the problem was re-examined with emphasis on laboratory studies where these two factors could be controlled more readily.

In Rhode Island there is one generation of the potato flea beetle annually and often a wide fluctuation in population from year to year. The overwintering adults emerge from hibernation in early or mid-May and are present in potato fields until early July. The new generation of adults begins to appear in mid-July, ordinarily is most numerous during the latter part of the month, and then gradually diminishes in number during August and early September. In 1957, adults of the new generation began to appear on July 15; in 1958, on July 21.

Methods and Materials.—For use in laboratory studies adult beetles were collected from two different potato fields at the intervals indicated in table 1. Field A was located in an area of intensive potato production where 7 to 9 pounds per acre of actual DDT was applied annually for insect control during the 10-year period from 1946 to 1955. Contrariwise, field B, which was not located in an area of intensive potato production, was approximately 1 mile distant from the nearest potato field and had received 3 to 4 pounds of actual DDT per acre annually in 6 of the years of the above-mentioned period. Neither field received DDT during 1957 or 1958.

The insects were collected with a 12-inch net, transferred to field containers, and used in laboratory studies within 1 hour. They were allowed to migrate freely from the field containers into glass jars which had been treated previously with DDT or were untreated. The studies were conducted under conditions of room temperature, which varied little from that existing out of doors, and of continuous light, both daylight and artificial. The inside of each jar and its aluminum foil cover, the total area of which was calculated to be 200 square inches, was treated with a solution of technical grade DDT in acetone, the desired rate of deposition being either 1.5, 3, 6, 12, or 24 micrograms per square inch. The actual deposits were found to vary only slightly from the desired values and were determined chemically by a modification of the Haller-Schechter method.

Two jars, each containing an average of 180 beetles, were used at each dosage rate. The test period was either 24 or 48 hours. Complete absence of external body movement was the criterion for death. As a result, many beetles that exhibited body tremors at the end of 24 hours were classified as live, but succumbed in the succeeding 24 hours. Toward the end of both seasons there was an increasing number of beetles in each test that were visibly unaffected by DDT even after exposure for 48 hours. The dosage-mortality data were plotted on logarithmic-probability paper, the lines fitted by eye and the LD-50 values interpolated or extrapolated, when necessary. The slope function of the regression lines was calculated according to the short method proposed by Litchfield (1949).

Results.—The data in table 1 show that the overwintered beetles from the two fields in both years succumbed readily to small deposits of DDT, the highest LD-50 value obtained in 24 hours being 3.4. In addition, the new generation became progressively more tolerant of the insecticide as the season advanced, the highest LD-50 values being obtained with beetles collected in late August and early September. The slope of the regression lines was relatively steep in the beginning and tended to flatten toward the end of each season.

Potatoes sprayed experimentally under field conditions with the type of hydraulic equipment generally available to potato producers in this State yielded data of which that in table 2 is representative. In this instance, where the population happened to be somewhat smaller than usual, the amounts of DDT indicated were applied to six, replicated 1/50-acre plots at the rate of 175 gallons per acre, the maximum gallonage obtainable with the equipment. This is 50 to 75 gallons in excess of that applied by the average potato producer. As shown in table 2, the residue obtained with the 2-pound rate, which at that time was the standard recommendation for potato flea beetle control in this State, was 23 micrograms per square inch of foliage surface. This was found to be greater than that on foliage sprayed by potato producers where values ranged from 6 to 18 micrograms per square inch with an average of 12.4 micrograms. As indicated in table 2, the 2-pound rate applied under the most optimum conditions resulted in a reduction of 82% in potato flea beetle population after 48 hours.

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[2] Entomologist and Agricultural Chemist, respectively.

Table 1.—Laboratory response of the potato flea beetle from two different fields to deposits of DDT. Kingston, Rhode Island, 1957–58.

	Field A				Field B			
	24 hours		48 hours		24 hours		48 hours	
Date	LD50	Slope[a]	LD50	Slope	LD50	Slope	LD50	Slope
	γ/sq. in.		γ/sq. in.		γ/sq. in.		γ/sq. in.	
1957								
June 12	0.6	5.6			1.2	6.8		
18	0.9	3.1			.2	3.9		
26	0.3	3.0			.1	12.2		
July 16	1.9	68.2						
19	15.2	28.4	1.2	35.9				
26	53.0	45.7						
Aug. 5	48.1	34.3	2.8	13.3	44.5	5.0	7.2	4.1
20	249.0	30.0			420.0	35.9		
28	92.0	12.6	5.1	13.2	51.0	8.5	6.2	7.3
Sept. 4					590.0	13.2	170.0	12.0
11			34.5	8.9				
1958								
June 10	3.0	2.3			3.4	12.6		
16	1.1	2.6			2.5	3.1		
23	1.7	2.8			1.0	5.8		
30					1.1	3.9		
July 7	1.1	2.2			1.0	4.5		
15					.3	4.6		
25					2.6	3.8		
28	23.5	12.2						
30					13.5	5.2		
Aug. 6	32.0	14.0			129.0	10.0		
12	179.0	21.5	4.8	2.8	152.0	23.6	7.0	7.4
20			4.0	16.0				
29	1075.0	29.8	22.1	18.5	280.0	39.7		

[a] Slope function $= \dfrac{\dfrac{LD84}{LD50} + \dfrac{LD50}{LD16}}{2}$.

In reviewing the data obtained at this station on the use of DDT for potato flea beetle control since 1946, it was found that, except for one instance in 1956 when an exceptionally large population appeared in the fields during June, the recommended rate of DDT has resulted in more than 90% reduction of the overwintered beetles. After the appearance of the new generation in mid-July, values ranging from 88% to 38% have been recorded for the same rate of application with the lower values being obtained more frequently during the latter part of the month. Therefore, it appears the DDT residues resulting from the 2-pound rate in the field have been sufficiently large to result in a relatively high degree of control of overwintered beetles, but have been insufficient against the new generation from late July to early September. Correlatively, the laboratory data indicated that the erratic field results obtained with DDT against the potato flea beetle have not been a matter of resistance but the phenomenon should be classified as "vigor tolerance," a term suggested by Hoskins & Gordon (1956).

Table 2.—Effect of 50W DDT on field control of the potato flea beetle. Kingston, Rhode Island, 1955.

Pounds in 100 Gal. Water	Insects in 100 Sweeps on Date Indicated[a]			
	July 11[b]	July 13	July 18	July 26
8	630 (85)	29	173 (32)	516 (3.7)
4	673 (39)	55	261 (16)	814 (1.7)
2	934 (23)	166	449 (9)	880 (1.1)

[a] Number in parenthesis represents micrograms of DDT per square inch of potato foliage.
[b] Denotes date sprays were applied.

Table 3.—Laboratory response of the potato flea beetle from two different fields to deposits of dieldrin. Kingston, Rhode Island, 1958.

	Field A		Field B			
	24 hours		24 hours		48 hours	
Date	LD50	Slope[a]	LD50	Slope	LD50	Slope
	γ/sq. in.		γ/sq. in.		γ/sq. in.	
June 10	<0.09		<0.09			
16	< .09		< .09			
25			< .09			
30	< .09		< .09			
July 8	< .09		< .09			
15			< .09			
24			< .09			
28	.04	225.0				
30			.27	10.8		
Aug. 6	.14	55.5	5.5	12.8		
11	28.0	81.8			0.043	13.0
19	7.0	6.9				
28	38.5	11.5				

[a] Slope function $= \dfrac{\dfrac{LD84}{LD50} + \dfrac{LD50}{LD16}}{2}$.

In 1956 dieldrin supplemented DDT as the standard recommendation for potato flea beetle control. The laboratory and field investigations of dieldrin reported here were less extensive than those of DDT, but the results are included because they are comparable. The conditions under which the work was conducted were similar to those described for DDT. In the laboratory in 1958 working at levels of 0.09, 0.19, 0.38, 0.75 and 1.5 micrograms per square inch of dieldrin (recrystallized 100% HEOD), 91 to 100% of the beetles from both fields succumbed in 24 hours in all tests until late July. The first two levels of deposit, 0.09 and 0.19, were calculated, since they were too small to determine accurately by chemical methods. From the mortality data it was impossible to extrapolate the LD-50 values since there was little or no slope to the regression lines. Therefore, as indicated in table 3, the actual LD-50 values for the dates previous to late July were unknown but were less than 0.09 microgram per square inch, the smallest deposit level used. Beginning in late July and continuing through late August the beetles became progressively more tolerant of dieldrin, as is evidenced by the LD-50 values presented.

REFERENCES CITED

Hoskins, W. M., and H. T. Gordon, 1956. Anthropod resistance to chemicals. Ann. Rev. Ent. 1: 89–122.

Litchfield, J. T., Jr. 1949. A method for rapid graphic solution of time-per cent effect curves. Jour. Pharm. and Exptl. Therap. 97: 399–408.

Toxicity of Some Alkylbenzyl Esters of Chrysanthemumic Acid and Two Related Esters in Comparison with Allethrin and Pyrethrins as House Fly Sprays[1]

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ABSTRACT

Twelve related synthetic compounds, most of them mono- and di-alkylbenzyl esters of *dl-cis-trans*-chrysanthemumic acid, were tested as space sprays against house flies, *Musca domestica* L. The most toxic were the *p*-ethylbenzyl and 2,4-dimethylbenzyl esters. They were, respectively, about 21 and 17% as toxic as allethrin, and 52 and 54% as toxic as pyrethrins at the 50% mortality level. Above this level the ratios were higher, reaching at the 95% mortality level to 31 and 20%, respectively, as toxic as allethrin and 88 and 91% as toxic as pyrethrins. The 3,4-dimethylbenzyl ester was about two-thirds as toxic as its 2,4-isomer. Saturation of the double bond in the acid component of this 2,4-isomer produced a compound one-third as toxic as the unsaturated compound. The knockdown value of the new esters, although excellent at highly toxic concentrations, was much inferior to that of allethrin or pyrethrins at comparable concentrations.

Among the many, relatively simple esters of *dl-cis-trans*-chrysanthemumic acids synthesized by Barthel and coworkers (Chen & Barthel 1956, Barthel & Alexander 1957, 1958) were a number of mono- and di-alkylbenzyl esters. In screening tests on some of them, Piquett & Gersdorff (1958 and unpublished work) found that several of the compounds, although less toxic than pyrethrins to house flies (*Musca domestica* L.), were sufficiently effective to warrant further work to evaluate their relative toxicities. This paper reports the results of this work. Tests with other compounds found of lower toxicity in the preliminary tests or untested by the same method were also made for comparative purposes because of close structural relationships.

EXPERIMENTAL PROCEDURE.—Allethrin and pyrethrins were used as standards of comparison. The sample of allethrin was of 93.4% purity as determined by the hydrogenolysis method. The sample of pyrethrins was the unrefined extractive in which 54.2% of the total pyrethrins consisted of pyrethrin I and cinerin I as determined by the mercury-reduction method. The samples of the new esters were of high purity.

After preliminary tests, sprays of the more toxic esters as well as the standards were prepared in refined kerosene (Deobase) at concentrations selected to cause a range of mortalities from low to high. Sprays of the esters of low toxicity were prepared in the same solvent at a single, relatively high concentration.

Knockdown and mortality of house flies of the National Association of Insecticide and Disinfectant Manufacturers' 1948 strain were determined in replicated tests by the Campbell turntable method. The tests were made in three series, each on a different group of six populations of flies. All sprays in a series were tested simultaneously and but once on each population in the group. The average age of flies was 2 to 3 days in series 1 and 3, and $1\frac{1}{2}$ to $2\frac{1}{2}$ days in series 2. The knockdown and mortality data are summarized in table 1.

EVALUATION OF RELATIVE TOXICITY.—To evaluate relative toxicity and determine the precision of the estimates, the mortality data for those materials tested at more than one concentration were subjected to probit analysis essentially as described by Finney (1952). Provisional individual regression lines were fitted. As was found previously in studies with alkoxybenzyl and piperonyl esters of chrysanthemumic acid (Gersdorff & Piquett 1958, 1959), it appeared that the extended data for the new synthetic compounds in series 2 and 3 could be adequately represented by parallel lines steeper than that for

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Table 1.—Knockdown and mortality of house flies caused by kerosene sprays containing certain new synthetic esters, allethrin, and pyrethrins.

Material	Concentration (Mg. per Dl.)	Per Cent: Knockdown in 25 Minutes	Per Cent: Mortality in 1 Day
Series 1. Six replicates, 105 flies each			
Chrysanthemumic acid, *p*-ethylbenzyl ester	888.9	79.0	90.2
	592.6	64.9	78.8
	395.1	33.8	60.2
	263.4	21.9	36.5
	175.6	6.1	10.3
	117.1	1.8	4.4
Allethrin	214.1	100	87.2
	142.8	100	77.6
	95.17	100	59.7
	63.45	100	45.1
	42.30	98.9	26.6
	28.20	97.4	10.9
Pyrethrins	759.4	100	92.2
	506.3	100	87.2
	337.5	100	73.1
	225.0	100	55.4
	150.0	100	43.1
	100.0	100	25.7
	66.67	99.0	14.8
Series 2. Six replicates, 110 flies each			
Chrysanthemumic acid, 2,4-dimethylbenzyl ester	1500	100	88.7
	1000	99.9	75.2
	666.7	97.0	56.1
	444.4	78.3	28.0
	296.3	61.4	5.8
3,4-dimethylbenzyl ester	2000	100	81.4
	1333	98.7	69.8
	888.9	97.1	41.6
	592.6	82.6	14.9
	395.1	72.6	5.8
m-methylbenzyl ester	3000	99.1	39.9
o-methylbenzyl ester	3000	100	66.0
Allethrin	214.1	100	79.6
	142.8	100	64.1
	95.17	100	47.3
	63.45	100	22.5
	42.30	100	8.1
	28.20	99.0	2.1
Pyrethrins	759.4	100	79.7
	506.3	100	65.2
	337.5	100	45.4
	225.0	100	28.9
	150.0	100	20.1
	100.0	100	8.9
	66.67	99.7	2.6
Series 3. Six replicates, 102 flies each			
Chrysanthemumic acid, *α*-allylcuminyl ester	3000	0	1.5
benzhydryl ester	3000	0	0.3
benzyl ester	3000	99.1	13.3
p-tert-butylbenzyl ester	3000	0	0.2
cuminyl ester	2000	1.0	46.6
	1333	0.5	25.3
	888.9	0.4	3.8
	592.6	0	0.9
p-methyl(*α*-propyl)benzyl ester	3000	0	0.5
Cyclopropanecarboxylic acid, 2-isobutyl-3,3-dimethyl-,2,4-dimethylbenzyl ester	2000	79.8	51.2
	1333	53.3	20.0
	888.9	25.3	5.7
	592.6	17.3	1.5
Allethrin	214.1	100	83.6
	142.8	100	66.3
	95.17	100	36.3
	63.45	100	22.1
	42.30	99.6	8.7
Pyrethrins	759.4	100	86.8
	506.3	100	73.5
	337.5	100	52.9
	225.0	100	41.9
	150.0	100	20.1
	100.0	100	7.8

allethrin. The statistical procedures based on this hypothesis were followed to obtain the weighted regression lines, and subsequent analysis of chi-squares gave no evidence that these data should not be so represented. The rest of the data required individually fitted lines. In some cases heterogeneity factors were required in the calculation of variances.

The final equations showing the regression of mortality, expressed in probits, on concentration in milligrams per deciliter, expressed as logarithms, are given below. Heterogeneity factors (H.F.) and the standard errors (s_b) of the regression coefficients are also given.

		s_b	H.F.
Series 1:			
Chrysanthemumic acid, *p*-ethylbenzyl ester	$Y=3.5897X-4.1676$	0.180	3.361
Allethrin	$Y=2.6394X+0.0474$	.082	1
Pyrethrins	$Y=2.3866X-0.4117$	.068	1
Series 2:			
Chrysanthemumic acid, 2,4-dimethylbenzyl ester	$Y=3.7511X-5.5746$	0.224	7.408
3,4-dimethylbenzyl ester	$Y=3.7511X-6.3339$	.224	7.408
Allethrin	$Y=3.1957X-1.5248$	.173	3.337
Pyrethrins	$Y=2.4908X-1.3619$	.071	1
Series 3:			
Chrysanthemumic acid, cuminyl ester	$Y=4.4310X-9.6557$	0.303	3.678
Cyclopropanecarboxylic acid, 2-isobutyl-3,3-dimethyl-, 2,4-dimethylbenzyl ester	$Y=4.4310X-9.6283$	.303	3.678
Allethrin	$Y=3.3546X-1.8602$	.218	3.541
Pyrethrins	$Y=2.7790X-1.8829$	.144	2.769

From these equations LC-50's were determined and evaluations of relative toxicity were then obtained as the inverse ratio of the pertinent pair of LC-50's. The esti-

Table 2.—Toxicity relative to allethrin and pyrethrins of some new synthetic esters.

MATERIAL	SERIES	LC-50[a] (MG. PER DL.)	PER CENT			
			Toxicity Relative to—		Range in Ratio to—	
			Allethrin	Pyrethrins	Allethrin	Pyrethrins
Chrysanthemumic acid, benzyl ester	3	—	1.7	4.0	—	—
cuminyl ester	3	2030 ±85	5.46±0.30	14.8± 0.8	4.2– 7.2	8.9– 24.5
2,4-dimethylbenzyl ester	2	659 ±28	16.70±0.89	54.3± 2.6	14.0–19.9	32.6– 90.6
3,4-dimethylbenzyl ester	2	1051 ±45	10.48±0.56	34.1± 1.6	8.8–12.5	20.5– 56.8
p-ethylbenzyl ester	1	358 ±11	21.01±0.74	51.7± 1.9	14.4–30.7	30.4– 88.1
m-methylbenzyl ester	2	—	3.1	9.4	—	—
o-methylbenzyl ester	2	—	4.9	17.4	—	—
Cyclopropanecarboxylic acid, 2-isobutyl-3,3-dimethyl-, 2,4-dimethylbenzyl ester	3	2001 ±81	5.54±0.29	15.0± 0.8	4.2– 7.3	9.0–24.9
Allethrin	1	75.23± 1.47	100	246.2± 7.0	100	211–286
	2	110.1 ± 3.6	100	325.3±12.7	100	233–455
	3	110.9 ± 3.8	100	270.2±12.7	100	214–341
Pyrethrins	1	185.2 ± 3.9	40.62±1.16	100	47.3–34.9	100
	2	358.2 ± 7.7	30.73±1.20	100	43.0–22.0	100
	3	299.7 ± 9.7	37.01±1.74	100	46.8–29.3	100

[a] For the compounds for which no LC-50's are given, the equieffective concentrations of the standards are, in the order named: of allethrin, 51.7, 91.6, and 148; and of pyrethrins, 119, 283, and 525 mg. per deciliter.

mations together with their standard errors are given in table 2.

Three compounds tested at the single concentration caused decided mortalities, as shown in table 1. These were the benzyl, *o*-benzyl, and *m*-benzyl esters. Estimates of their relative toxicities were obtained simply by comparison of the actual concentration of their sprays with the equally effective concentrations of each standard as determined from their equations.

Since the regression lines determined for the benzyl esters are steeper than those for allethrin and therefore those for pyrethrins, ratios of comparison with these standards will increase between low and high mortality levels. Such ratios were estimated from LC-5's and LC-95's determined directly from the equations and are also given in table 2 to indicate the approximate range possible.

DISCUSSION.—The most toxic of the new compounds were the *p*-ethylbenzyl and the 2,4-dimethylbenzyl esters. They were nearly equal, about one-fifth as toxic as allethrin and half as toxic as pyrethrins at the 50% mortality level. The enlargement of the side chain in the *p*-ethylbenzyl ester to the *p*-isopropyl group (in the cuminyl ester) was accompanied by a loss in toxicity of about 73% (74.0% when relative toxicity is based on allethrin and 71.4% when it is based on pyrethrins). The change of the two methyl groups from the 2,4 to the 3,4 position in the dimethylbenzyl esters was accompanied by a loss in toxicity of about 37% on either basis. The results of screening work (Piquett & Gersdorff 1958) with the 2,5-dimethylbenzyl ester, which was unavailable for inclusion in this study, show the change to this position to be accompanied by an even greater loss in toxicity.

The 2,4-dimethylbenzyl ester of 2-isobutyl-3,3-dimethylcyclopropanecarboxylic acid (dihydrochrysanthemumic acid) was about one-third as toxic as the corresponding ester of the unsaturated acid. A similar structural change to saturation in the acid component has been found in previous work to result in esters having toxicity ratios of about one-half when the alcoholic component was pyrethrolone or cinerolone (Gersdorff 1947) or piperonyl alcohol (Gersdorff & Piquett 1959), and about one-third when it was allethrolone (LaForge *et al.* 1952).

At the 95% mortality level the best two compounds were nearly (90%) as toxic as pyrethrins.

As was found (Gersdorff & Piquett 1958, 1959) with other esters of chrysanthemumic acid formed by alcohols simpler in structure than allethrolone, the knockdown values of the toxic ones of these alkylbenzyl esters, although excellent at highly toxic concentrations, were much inferior to that of allethrin at comparable concentrations.

REFERENCES CITED

Barthel, W. F., and B. H. Alexander. 1957. Screening tests of miscellaneous compounds containing the methylenedioxyphenyl structure. U. S. Dept. Agric., ARS-33-27, 24 pp.

Barthel, W. F., and B. H. Alexander. 1958. Preparation of the chrysanthemumates of 6-bromo- and 6-chloropiperonyl alcohols. Jour. Organ. Chem. **23**(7): 1012–14.

Chen, Yuh-Lin, and W. F. Barthel. 1956. Screening tests of esters of chrysanthemumic acid as synergists and insecticides. U. S. Dept. Agric., ARS-33-23, 10 pp.

Finney, D. J. 1952. Probit analysis. 318 pp. Cambridge.

Gersdorff, W. A. 1947. Toxicity to house flies of the pyrethrins and cinerins, and derivatives, in relation to chemical structure. Jour. Econ. Ent. **40**(6): 878–82.

Gersdorff, W. A., and P. G. Piquett. 1958. The toxicity of certain alkoxybenzyl esters of chrysanthemumic acid in comparison with allethrin and pyrethrins as house fly sprays. Jour. Econ. Ent. **51**(6): 810–12.

Gersdorff, W. A. , and P. G. Piquett. 1959. Toxicity of the piperonyl ester of chrysanthemumic acid and some of its derivatives in comparison with allethrin and pyrethrins as house fly sprays. Jour. Econ. Ent. **52**(1): 85–88.

LaForge, F. B., W. A. Gersdorff, Nathan Green, and M. S. Schechter. 1952. Allethrin-type esters of cyclopropanecarboxylic acids and their relative toxicities to house flies. Jour. Organ. Chem. 17(3): 381–9.

Piquett, P. G., and W. A. Gersdorff. 1958. Screening tests with some synthetic compounds for toxicity to house flies when applied as space sprays. Jour. Econ. Ent. 51(6): 791–3.

Cattle Grub Control with Ronnel[1]

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ABSTRACT

Ronnel (*O,O,*-dimethyl *O*-(2,4,5-trichlorophenyl) phosphorothioate; formerly designated Korlan, Trolene, or Dow ET-57) was administered orally to calves and yearlings in Nebraska for the control of *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.). It was given in a suspension at the rate of 100 mg. per kilogram of body weight 6 to 10 weeks before grubs began appearing in the backs. The percentages of control of grubs in three groups of cattle were approximately 75, 89, and 94. The grubs were most abundant in February, March, and April in decreasing order. *H. lineatum* were slightly more abundant than *bovis*. Calves that were infested when only a few weeks old had approximately twice as many grubs as yearlings.

The systemic effect of ronnel (*O,O*-dimethyl *O*-(2,4,5-trichlorophenyl) phosphorothioate; formerly designated Korlan, Trolene, or Dow ET-57) in controlling the cattle grubs *Hypoderma lineatum* (De Vill.) and *H. bovis* (L.) has been reported by several workers. The first ones to publish results were McGregor & Bushland (1957) in Texas and Roth & Eddy (1957) in Oregon. Jones & Brundrett (1957) working in Texas and Adkins (1957) in Alabama obtained 87% control of *lineatum* in field tests. Graham *et al.* (1957) reported its use against larvae of *Dermatobia hominis* (L., Jr.) in Panama. All these workers administered the compound orally at approximately 100 mg. per kilogram of body weight. Its use in controlling mixed populations of *lineatum* and *bovis* in Nebraska was demonstrated by Jones & Matsushima (unpublished). A high degree of control was obtained in both feed-lot and wintering calves when the chemical was administered as a drench or bolus at the same rate.

During the 1956-57 season additional tests were conducted in Nebraska at a typical ranch in the Sandhills and at the Fort Robinson Beef Cattle Research Station.

Forty-six Hereford calves and yearlings on the Sandhills ranch were used in two grub-control and weight-gain tests. The first test consisted of 22 animals, 11 of which were treated on October 5, approximately 2½ months before grubs encysted in their backs. The second test consisted of 24 animals, 12 of which were treated on November 3. In a third test, conducted at the Fort Robinson Beef Cattle Research Station, 37 Hereford and Angus calves were treated on November 1, and 10 animals were selected at random as controls.

In all three tests the treated animals were given a drench containing a 10% suspension of ronnel, prepared from a wettable powder containing 25%. The suspension was administered from a bottle at the rate of 1 ml. per kilogram of body weight. The animals were weighed on the day of treatment.

Examination of each animal for grubs was made at monthly intervals from January through May at the Sandhills ranch, and from January through April at Fort Robinson. A cumulative count in each treated animal was obtained by indicating the position of each grub on a chart. In some of the untreated animals the grubs were too numerous to plot accurately on a chart; therefore, the figures represent the largest number found at one time.

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[2] In cooperation with the Department of Entomology, Nebraska Agricultural Experiment Station, Lincoln. The cooperation of R. M. Koch, director of the Fort Robinson Beef Cattle Research Station, Crawford, and Glenn Buck, owner of the ranch located in the Sandhills near Valentine, and the help provided by them in handling the cattle are acknowledged.

Table 1.—Effects of ronnel administered orally to cattle at the rate of 100 mg./kg. for control of cattle grubs, 1956.

Test Group	No. of Animals		Average Number of Grubs for All Animals					
				Monthly				
	Total	With Grubs	Seasonal	Jan.	Feb.	Mar.	Apr.	May
Sandhills ranch:								
Test 1								
Treated Oct. 5	11	5	0.9	0.1	0.5	0.5	0.3	0.2
Untreated	11	11	16.1	2.7	12.3	11.0	9.4	3.4
Test 2								
Treated Nov. 3	12	7	1.4	0.1	0.7	0.4	0.7	0.4
Untreated	12	12	13.2	3.0	11.1	10.1	8.0	1.5
Fort Robinson:								
Treated Nov. 1	37	22	2.7	0.03	2.4	1.2	0.3	—
Untreated	10	10	10.8	2.4	8.8	7.5	5.6	—

Table 2.—Number of grubs in untreated animals of different ages, Sandhills ranch.

Months	Number of Animals	Number of Grubs per Animal	
		Range	Average
6	6	14–33	23.0**
12	9	1–23	11.8
18	8	4–23	11.4

** Significant at 1% level. L.S.D. equals 9.445.

The cattle at the Sandhills ranch were weighed 1 month after treatment and at the close of the grub season to determine whether the insecticide or resulting decrease in number of grubs affected their weights.

The results of the experiments are summarized in table 1. Ronnel was very effective in controlling cattle grubs in both tests at the Sandhills ranch. During the first month both treated and untreated animals of the two groups lost weight. The rancher attributed this loss to bad weather. When the final weights were taken, all groups had gained. The gains made by the untreated animals were slightly greater, but not significantly so.

At Fort Robinson, the factors relating to the effectiveness of ronnel appeared to be the same as at the Sandhills ranch, but grub control was not so good. The treated animals had an average of 2.7 grubs each. The individual infestations varied from zero in 15 animals to 13 in 3 animals.

The monthly occurrence of grubs in the backs of the cattle is shown in table 1. Large numbers were observed in February, March, and April in decreasing order. Only a few grubs were observed in January and May. Examination of a small number of extracted grubs indicated that approximately 60% of those that encysted in February and 45% of those that encysted in March were *lineatum*.

Data in table 2 bear out the observation of many cattlemen that calves harbor more grubs than older animals. The animals involved had been pastured since birth on the same ranch. The calves had more than twice the number of grubs as the yearlings.

References Cited

Adkins, Theodore R., Jr. 1957. Field evaluation of Dow ET-57 as a systemic insecticide for the control of the common cattle grub in Alabama. Jour. Econ. Ent. **50**(4): 474–6.

Graham, O. H., L. L. Wade, R. W. Colby, and W. S. McGregor. 1957. Use of Dow ET-57 for the systemic control of *Dermatobia hominis* in cattle. Agric. Chemicals **12**(10): 51, 109.

Jones, Calvin M., and J. Matsushima. The effects of Dow ET-57 on control of cattle grubs and weight gains of beef cattle. Nebraska Agric. Expt. Sta. Unpublished.

Jones, Robert Henry, and H. M. Brundrett. 1957. Ranch tests against cattle grubs with the systemic insecticide Dow ET-57. Agric. Chemicals **12**(7): 45, 95–6.

McGregor, W. S., and R. C. Bushland. 1957. Tests with Dow ET-57 against two species of cattle grubs. Jour. Econ. Ent. **50**(3): 246–9.

Roth, A. R., and G. W. Eddy. 1957. Tests with Dow ET-57 against cattle grubs in Oregon. Jour. Econ. Ent. **50**(3): 244–6.

A New Method of Using Lindane Crystals for Protecting Boxed Woolens against Fabric-Insect Damage[1]

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Abstract

Long-term storage tests reported elsewhere showed that lindane crystals at 5 gm./cu. ft. protected boxed woolens against insect damage for 3 years or longer, whereas naphthalene crystals at 46 gm./cu. ft. gave protection for only 1 year. To overcome the objection of having loose lindane crystals throughout the clothing when unpacked, a new method was developed for preparing and applying the lindane crystals. This consisted of adhering the crystals to sheets of paper of fiberboard with the aid of a fast-drying adhesive, and introducing the insecticide in the packing or storage containers in this form. The prepared units are referred to in this paper as "lindane boards." Laboratory tests conducted at the rate of 10 and 20 gm./cu. ft. of lindane showed that the lindane boards were as toxic to fabric insects as the loose crystals used at the same rate of application after an exposure of 14 to 21 days.

At the request of the Office of the Quartermaster General, U. S. Army, the effectiveness and duration of the naphthalene-crystal treatment used by Quartermaster for the protection of boxed, woolen uniforms was investigated. The treatment consisted of sprinkling naphthalene crystals at the rate of 6 ounces per box (46 gm./cu. ft.) through the uniforms as they were packed. The containers used were wooden boxes lined with asphalt-laminated paper envelopes which formed a rather air-tight package for the protection of the clothing against dust and moisture. Under environmental storage conditions at Savannah, Georgia, the effective protection rendered by this treatment lasted only 1 year, the naphthalene crystals having completely volatilized in that period of time. The cost involved in the yearly replacement of naphthalene crystals led to the investigation of lindane crystals for this purpose. Laboratory tests showed that lindane vapors were very toxic to fabric insects. A large-scale storage test showed that lindane crystals applied at the rate of 5 grams per cubic foot in the same manner described above for the naphthalene were effective in protecting the woolens against damage for a minimum of 3 years. At the end of this period of storage, approximately

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[2] One of the field stations of the Stored-Product Insects Section, Biological Sciences Branch, Marketing Research Division, Agricultural Marketing Service, U. S. Department of Agriculture.

Table 1.—Percentage of dead (D) and moribund (M) black carpet beetle larvae exposed to vapors from loose lindane crystals and lindane adhered to paper.

Method	Rate of Application (Gm./Cu. Ft.)	Days Exposed	Postexposure—Days							
			0		7		14		21	
			Per Cent							
			D	D+M	D	D+M	D	D+M	D	D+M
Adhered	20	3	0	3	3	10	8	10	10	10
	10		0	8	8	10	10	10	10	18
Loose	10		0	3	10	18	20	20	20	25
Check	0		0	0	0	0	0	0	0	0
Adhered	20	7	3	11	10	23	26	31	41	49
	10		5	10	10	18	15	18	15	18
Loose	10		0	5	15	18	20	30	33	41
Check	0		0	0	0	0	0	0	0	0
Adhered	20	14	50	68	68	73	80	83	83	86
	10		28	41	70	80	78	91	93	100
Loose	10		48	76	80	90	88	93	93	98
Check	0		0	0	0	0	0	0	0	0
Adhered	20	21	100	100	100	100	100	100	100	100
	10		85	98	100	100	100	100	100	100
Loose	10		100	100	100	100	100	100	100	100
Check	0		0	0	0	0	0	0	0	0

35% of the lindane by weight was still in the crystalline form (Laudani 1958).

There was concern about the possible toxicity hazard created by the presence of the loose crystals when the uniforms were unpacked for troop issue. It was suggested that lindane be introduced into the boxes in another form which would not have the same objection. The use of sprays, dusts, and impregnated felts and boards was considered but each of these appeared to create possible toxicity hazards to the men packing or unpacking the uniforms more serious than those of the loose lindane crystals. This problem was overcome by developing a new method of preparing and applying lindane crystals. A description of the method and the relative toxicity to fabric insects as compared to the use of loose crystals is given herein.

PROCEDURE.—The new method of preparing and applying lindane crystals consisted of adhering the insecticide to sheets of paper or fiberboard with the use of a fast-drying adhesive. The finished product is referred to in this paper as "lindane boards." In the test described below, a vinyl-plastic base adhesive was applied to 50-lb. kraft paper with the use of an Automatic Blade Applicator.[3] The paper was placed on the vacuum plate and a 6-inch film applicator was automatically drawn down the length of the paper as a steady flow of the adhesive was fed in front of the blade. Immediately after the adhesive was applied, a known amount of lindane crystals was sprinkled over the coated surface. The paper was cradled gently until all of the crystals had adhered to the treated surface. The amount of lindane per square foot can be governed by controlling the amount of adhesive used. The technical lindane used for the treatments was such that 8% of the crystals were retained on a 40-mesh screen, 49% on a 60-mesh screen, 8% on an 80-mesh screen, and the remaining 35% passed through.

Vapor tests comparing the toxicity to fabric insects of the lindane board and the loose crystals were conducted in 5-gallon glass jars having a volume of approximately 0.7 cubic foot. The jars were placed in a horizontal position and the treated papers and loose crystals introduced. The loose crystals were spread over an area approximately equal to the area covered by the crystals on the lindane board treated at the rate of 10 grams per cubic foot. After the introduction of the insecticide, the jars were sealed and allowed to remain for 7 days before the test insects were introduced.

The fabric insects used for this test were 3- to 5-month-old larvae of the black carpet beetle, *Attagenus piceus* (Oliv.), and late-instar larvae of the furniture carpet beetle, *Anthrenus flavipes* Lec. The insects were caged in cylindrical 40-mesh screen cages, 4″ long and 1″ in diameter, partitioned to provide two compartments per cage. Four cages were fastened together in such a manner as to form a long cylinder having a total of eight separate chambers for test insects. Four replications of 10 larvae each of both species were contained in each cylinder. One cylinder was introduced for each of the following exposure periods: 3, 7, 14, and 21 days. The cylinders were inserted through portholes in the jar lid and held suspended in two tiers 4 and 5 inches above the insecticide. The insects were removed at the end of each exposure period, placed in clean petri dishes, and closely examined immediately and again after 7, 14, and 21 days. The percentage of insects moribund and dead was recorded. All exposures and postexposures were made in a room having 80° ± 2° F. temperature and 60 ± 5% relative humidity.

RESULTS.—The results with the black barpet beetle larvae are shown in table 1 and those with the furniture carpet beetle larvae in table 2. It will be noted that at equal rates of application the loose crystals produced higher kills of both species at exposures of 3 and 7 days.

[3] ASTM Designation D823-51T.

Table 2.—Percentage of dead (D) and moribund (M) furniture carpet beetle larvae exposed to vapors from loose lindane crystals and lindane adhered to paper.

METHOD	RATE OF APPLICATION (GM./CU. FT.)	DAYS EXPOSED	POSTEXPOSURE—DAYS							
			0		7		14		21	
			Per Cent							
			D	D+M	D	D+M	D	D+M	D	D+M
Adhered	20	3	13	60	63	83	80	85	85	88
	10		5	40	40	68	73	73	73	76
Loose	10		10	68	78	88	93	95	95	95
Check	0		0	0	0	0	8	8	8	11
Adhered	20	7	48	76	83	100	93	100	98	100
	10		54	77	90	98	98	98	98	98
Loose	10		54	80	90	100	98	100	100	100
Check	0		3	3	3	3	3	3	3	3
Adhered	20	14	90	100	95	100	100	100	100	100
	10		90	100	98	100	100	100	100	100
Loose	10		93	100	98	100	100	100	100	100
Check	0		3	3	3	3	3	3	3	3
Adhered	20	21	95	100	100	100	100	100	100	100
	10		98	100	98	100	100	100	100	100
Loose	10		100	100	100	100	100	100	100	100
Check	0		4	4	10	10	10	10	10	13

At exposures of 14 and 21 days the toxicity of the boards and the loose crystals was about equal, especially beyond the 7-day postexposure period. This appeared to indicate that the initial release of toxic vapors was greater by the loose crystals but in 14 to 21 days the concentration of lindane in the air emitted by both forms produced approximately the same insect mortality.

A comparison of the results obtained with the lindane boards at 10 and 20 grams of lindane per cubic foot of air shows that the higher concentration produced slightly higher mortalities at the shorter exposures. With 14- and 21-day exposure periods the results obtained with the lindane board at 20 grams per cubic foot were about the same as those with the loose crystals at 10 grams per cubic foot.

DISCUSSION.—Army uniforms are generally tied in bundles having a flat cardboard divider. A storage box contains three or more such bundles. By using dividers which have been coated with lindane crystals as described above, the necessary amount of insecticide can be introduced in each box. Using lindane in this form has a number of advantages over the use of loose crystals. It eliminates the objection of having loose crystals through the clothing. The disposal of the excess insecticide when the clothing is removed from the boxes is greatly facilitated, for the treated boards can be easily discarded or burned, the directions for which can be printed right on the boards. It enables the personnel packing or unpacking the uniforms to handle the lindane boards without touching the insecticide, since the edges of the boards can be left untreated for handling purposes.

The method described above is not recommended for use in areas where occupancy is greater than 40 hours a week until further studies can be conducted on the possible danger of this treatment.

REFERENCE CITED

Laudani, Hamilton. 1958. Methods for the protection of woolen materials tested by the U.S.D.A. Savannah laboratory. Proc. Tenth Internatl. Congr. Ent. Montreal, Canada. **4**: 35–43.

Adsorption of DDT and Its Absorption and Conversion to DDE by House Flies Exposed to Residues[1]

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Abstract

The rate of adsorption of DDT from residues on glass surfaces and its absorption and conversion to DDE (1,1-dichloro-2,2-bis(*p*-chlorophenyl)ethylene) was evaluated in a normal colony and three resistant colonies of house flies (*Musca domestica* L.). External DDT increased with the time of exposure and with fly activity in two of three colonies. Different colonies of flies picked up DDT at different rates. Detoxification of DDT to DDE increased with time of exposure. Knocked-down flies showed more absorbed DDT than those still up at the end of the exposure period, and less conversion of DDT to DDE. Susceptible flies showed the presence of a DDT-DDE detoxifying mechanism after prolonged exposure to DDT residues, and a colony selected with malathion converted DDT to DDE in short exposures.

The cuticle is the principal site of insecticide uptake by flies exposed to DDT residues. The phenomenon of cuticular uptake, particularly by the appendages, has been demonstrated in muscid flies by Potts & Vanderplank (1945), Lindquist *et al.* (1951), and Gratwick (1957). Sternburg *et al.* (1950) and Lindquist *et al.* (1951) further indicated that in resistant insects cuticular DDT is readily absorbed and transferred to the area where detoxification to DDE (1,1-dichloro-2,2-bis(*p*-chlorophenyl) ethylene) takes place.

In tests with insecticide residues it has been presumed that the amount of insecticide acquired by the insects could be varied in either of two ways—by changing the amount of insecticide per unit of surface or the time that the insects are exposed thereon. Continuous exposures on residues of chlordane, dieldrin, and lindane have been used to measure resistance in cockroaches (Keller *et al.* 1956), the length of exposure required to cause knockdown being correlated with the degree of resistance. Presumably the difference in knockdown time is due not so much to differences in time of reaction to the insecticide as to differences in the amounts of insecticide acquired cumulatively over the entire exposure period.

In studies with house flies (*Musca domestica* L.) continuous exposure to residues of several insecticides other than DDT provided satisfactory measurements of resistance. In tests with DDT, however, it was observed that the results with flies of the LDD colony (moderately resistant to lindane, DDT, and diedrin) did not follow the same pattern as those with flies from two other colonies, one resistant and the other normal. A series of tests was therefore undertaken to determine whether the total amount of DDT acquired was proportional to the time of exposure, and whether different strains of flies varied in the amounts acquired by the same exposure. Since the acquired dose (amount adsorbed) was being progressively absorbed, it was necessary to recover the DDT present internally as well as externally, and since the resistant flies were detoxifying the DDT it was necessary to analyze for DDE as well as DDT.

Material and Methods.—Four colonies of flies were used—the Orlando No. 1, completely resistant to DDT; the LDD colony, moderately resistant to lindane, DDT, and dieldrin; the M colony, moderately resistant to malathion and DDT; and the normal colony, never exposed to DDT and highly susceptible to all insecticides. An evaluation of the resistance of these colonies has been reported by Wilson *et al.* (1959).

Flies were confined in pint glass jars containing residues of 2.0 or 3.5 mg. of *p,p'*-DDT per square foot. To obtain the desired residue, 2.5 ml. of an acetone solution containing 0.02% or 0.035% of the insecticide was applied to the inner surface of the jar, which was then rotated so that the solution washed over the entire inner surface up to the neck until the acetone had completely evaporated. These light residues were used to provide an exposure of at least 30 minutes without causing high or complete knockdown.

The flies were anesthetized with carbon dioxide and groups of 125 females were placed in cylindrical wire cages. When completely recovered from the anesthesia, the flies were transferred to the treated jars. The jars were then covered with heavy cards, inverted, and the flies exposed for periods of 10 to 1,080 minutes. The flies that were knocked down by the insecticide fell to the untreated card. After the exposure period, they were removed, counted, and assayed for DDT and DDE. The remaining flies were anesthetized while the jar was still inverted and allowed to fall to the card, from which they were removed, counted, and assayed in the same manner as the knocked-down flies. This procedure was followed in order to prevent the flies from contacting the residue after they were knocked down by insecticide or anesthesia. Additional tests were made in which flies of the normal colony and the M colony were exposed for 300 minutes in a treated jar inverted directly over another treated jar, so that knocked-down flies fell onto a treated surface. This was done to increase the amount of DDT absorbed in the flies to provide a larger quantitative measurement of the rate of conversion to DDE.

To recover the external DDT, samples of 100 flies were immediately rinsed with seven 10-ml. portions of freshly distilled ether. The solvent was evaporated under reduced pressure, and the residue was analyzed for DDT.

The internal DDT and DDE were recovered from the washed flies in a manner similar to that described by Sternburg *et al.* (1950). The flies were homogenized in the presence of 3 grams of anhydrous sodium sulfate and extracted with seven 10-ml. portions of distilled ether. The extracts were then combined and evaporated under reduced pressure, and the residue was analyzed for DDT and DDE. Washing and homogenization immediately upon termination of the exposure period were necessary to prevent further absorption of DDT from the exterior of the flies and to prevent the conversion of internal DDT

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to DDE. Concurrently, the same numbers of untreated flies and of untreated flies homogenized with known quantities of DDT and DDE were carried through the entire procedure. The results of the former were used as blank corrections and those of the latter to correct the analytical results for per cent recovery.

The analyses for DDT and DDE were performed by the colorimetric method of Schechter *et al.* (1945) as modified by Sternburg *et al.* (1950), but the nitrated product was treated with 1 ml. of benzene and 2 ml. of methanolic sodium methylate. The optical densities were measured in cells 1 cm. square with a Beckman DU spectrophotometer. In this method the maximum absorption for DDT is at a wavelength of 596 millimicrons and the maximum for DDE is at 520 millimicrons. Absorbance measurements were made at both wavelengths and blank corrections were applied. The quantity of each constituent in micrograms per 100 flies was calculated by simultaneous equations.

Results.—The results are given in table 1. There was a progressive increase in the uptake and absorption of DDT with increasing exposure periods by flies of the normal and No. 1 colonies, but little correlation between uptake and time of exposure in flies of the LDD colony. Time of exposure was therefore a less reliable method of regulating the dosage with this strain than with the other two strains. With the LDD strain the amount of residue influenced the absorption to a much greater degree than the exposure period.

There was considerable difference in the amount of DDT picked up by different strains of flies exposed to the same residue for the same period of time. Flies of the No. 1 colony picked up DDT at the lowest rate, and flies of the normal colony at the highest; however, the No. 1 flies absorbed a slightly higher proportion of the adsorbed DDT. It was noted that flies of the No. 1 strain remained almost stationary on the treated surfaces during the exposure period, whereas those from the normal strain were very active, which probably accounted for at least a part of the difference in pickup.

As expected, the conversion of internal DDT to DDE generally increased with the time of exposure and the ratio of conversion of the four strains generally increased with the degree of resistance. This is in accordance with the results obtained by Perry *et al.* (1953) using topical applications, whereas Lindquist *et al.* (1951) reported the rates of metabolism of topically applied DDT to be similar in resistant and susceptible strains of flies.

The flies of the normal colony that were knocked down by exposure to the DDT residue contained more internal DDT than the flies that were still up at the end of the exposure period. The LDD flies that were knocked down also showed more absorbed DDT, but less DDE and less external DDT, than flies that were still up. In the LDD strain the ratio of DDT converted to DDE was much higher in long exposures to low residues than in shorter exposures to higher residues. Usually the amount of DDE exceeded the amount of unconverted absorbed DDT in No. 1 flies, none of which were knocked down by any exposure. However, after a long exposure these flies contained more unconverted DDT than required to cause knockdown and mortality of the normal flies.

Table 1.—External DDT and internal DDT and DDE in various colonies of house flies after exposure to residues of DDT in glass jars for various intervals.[a]

Condition of Flies	Exposure (Min.)	Per Cent Knockdown	Micrograms per 100 Flies[b]				
			External DDT	Internal			Total Uptake
				DDT	DDE	Total	
			Normal Colony				
Up	10	0	9.1	1.2	0	1.2	10.3
	20	38	29.9	4.7	0	4.7	34.6
	30	87	29.2	7.3	0	7.3	36.5
Down	20	38	22.1	6.4	0	6.4	28.5
	30	87	38.6	10.6	0	10.6	49.2
	300	100	112.0	19.3	12.5	31.8	143.8
			LDD Colony				
Up	10	0	8.6	0.2	0.9	1.1	9.7
	20	40	16.6	2.2	2.7	4.9	21.5
	30	60	17.2	2.4	2.7	5.1	22.3
	40	80	14.6	1.4	4.3	5.7	20.3
Up[c]	30	0	6.0	.8	0	0.8	6.8
	60	0	7.4	.4	3.9	4.3	11.7
	120	0	8.1	2.2	5.7	7.9	16.0
Down	20	40	11.0	3.5	2.2	5.7	16.7
	30	60	15.0	4.5	2.2	6.7	21.7
			No. 1 Colony				
Up	15	0	4.0	.8	1.8	2.6	6.6
	30	0	6.0	.7	1.8	2.5	8.5
	60	0	19.0	1.2	4.4	5.6	24.6
	120	0	24.2	5.0	5.1	10.1	34.3
	1,080	0	220.0	19.4	57.3	76.7	296.7
			M Colony				
Up	30	0	8.1	2.6	2.3	4.9	13.0
Down	300	100	100.8	26.2	100.0	126.2	227.0

[a] 1 to 3 tests; 3.5 mg. of DDT per sq. ft. except as noted.
[b] Based on molecular weight of DDT.
[c] 2.0 mg. of DDT per square foot.

Normal flies showed the presence of a detoxifying mechanism after prolonged exposure to DDT residues, but not after exposure to the same dosage for 30 minutes or less.

The M-colony flies converted DDT to DDE as rapidly as flies from the LDD colony, although the former had never previously been exposed to DDT. The M colony originated from the normal colony and was selected solely with malathion for more than 30 generations.

References Cited

Gratwick, M. 1957. The uptake of DDT and other lipophilic particles by blowflies walking over deposits. Bull. Ent. Res. **48**(4): 733–68.

Keller, J. C., P. H. Clark, C. S. Lofgren, and H. G. Wilson. 1956. Cockroach control. Pest Control **24**(9): 12–20.

Lindquist, A. W., A. R. Roth, W. W. Yates, and R. A. Hoffman. 1951. Use of radioactive tracers in studies of penetration and metabolism of DDT in house flies. Jour. Econ. Ent. **44**(2): 167–72.

Perry, A. S., R. W. Fay, and A. J. Buckner. 1953. Dehydrochlorination as a measure of DDT-resistance in house flies. Jour. Econ. Ent. **46**: 972–6.

Potts, W. H., and F. L. Vanderplank. 1945. Mode of entry of contact insecticides. Nature **156**: 112.

Schechter, M. S., D. B. Soloway, R. A. Hayes, and H. L. Haller. 1945. Colorimetric determination of DDT. Indust. and Engineer. Chem. Analyt. Ed. **17**: 704–9.

Sternburg, J., C. W. Kearns, and W. N. Bruce. 1950. Absorption and metabolism of DDT by resistant and susceptible house flies. Jour. Econ. Ent. **43**(2): 214–19.

Wilson, H. G., G. C. LaBrecque, J. B. Gahan, and Carroll N. Smith. 1959. Insecticide resistance in seven Orlando house fly colonies. Jour. Econ. Ent. **52**(2): 308–10.

SCIENTIFIC NOTES

Laboratory Studies of Pear Psyllas Resistant to Dieldrin and Some Related Compounds[1]

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Reports were received toward the end of the 1958 growing season that dieldrin sprays were not controlling the pear psylla (*Psylla pyricola* Foerst.) in some areas. Laboratory tests with insecticides under way at that time were therefore expanded to compare the efficiency of dieldrin and some other materials on dieldrin-resistant and susceptible strains.

Test specimens were obtained from infested shoots cut from sample trees and taken to the laboratory with their cut ends in a pail of water. Selected shoots were cut into small sections having one to three leaves, and the number of psyllas reduced to 10 nymphs by removing the oldest and youngest specimens. The infested cuttings were then placed with their stems in small bottles of water closed with cotton plugs covered with polyethylene wrap, and each was sprayed with 30 ml. of insecticide while revolving on a small turntable. The spray was stirred constantly during mixing and application and was delivered from a small atomizer rigidly mounted 20 inches from the plant. Each insecticide was applied in five concentrations by successively diluting the spray with equal amounts of water. For example, dieldrin was applied at 1, 0.5, 0.25, 0.125, and 0.0625 pound per 100 gallons. The treated cuttings were placed on a large table in the laboratory and after 48 hours the numbers of living psyllas were recorded.

In September psyllas from three locations near Yakima where failures in control with dieldrin had been reported were compared in laboratory tests with psyllas from an orchard near East Wenatchee where no similar difficulty had been experienced. Psyllas from each of the locations near Yakima were almost unaffected by the dieldrin sprays or by endrin and toxaphene, all of which killed substantial numbers of those from the East Wenatchee area. The mortality of the Yakima collections averaged 3.3% with dieldrin, 15.3 with endrin, and 17.3 with toxaphene, as compared with 62, 100, and 34% in the Wenatchee strain. Sevin® (N-methyl-1-naphthyl carbamate) which is quite different from dieldrin in chemical structure, gave higher kills of the Yakima psyllas than those from near Wenatchee.

In another comparison made later in the month, differences between the two strains were not so marked, but resistance was indicated by lower kills of the psyllas from Yakima with dieldrin, endrin, and toxaphene. The respective mortalities were 38, 36, and 54% as compared with corresponding 70, 82, and 68% for the Wentachee strain.

Late in September it was also reported that the pear psylla was very difficult to control in some orchards a few miles south of Wenatchee toward Malaga. Laboratory tests showed that these psyllas also were resistant to dieldrin and some related materials as compared with the strain from near East Wenatchee. This was consistently evident through seven replications. Average mortalites with dieldrin, endrin, and toxaphene were 19, 39, and 52%, respectively, for the Malaga strain and 76, 87, and 79% for the East Wenatchee strain. Sevin gave 92% in the Malaga strain and 73% in the one from East Wenatchee. This and similar results with the Yakima psyllas suggests that the dieldrin-resistant strains may have become more susceptible to Sevin.

Because of the heterogeneity that results from pooling data for the five different dilutions of each insecticide and other reasons, comparison of the present results in terms of average mortality is not the best method. Each insecticide was applied in five dilutions to permit comparison of the results in terms of dosage-mortality curves and the amounts necessary to kill 50% of the insects. Analyses of the data on this basis have not been completed, but estimated LD-50s indicate that, in comparison with the Wenatchee psyllas, about 10 times more dieldrin, 15 times more endrin, and three times more toxaphene would be necessary to kill 50% of the Malaga strain.

All cases of poor results or failures in insecticide control should not be attributed to resistance, but over a period of time some resistance may be expected as a natural and inevitable result of intensive control. No matter how effective an insecticide is found to be, it should not be regarded as a permanent safeguard. Continuing research will be necessary to maintain effective control of orchard insect pests.

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Parasites and Predators of *Fannia canicularis* (L.) and *Fannia scalaris* (F.)[1]

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During a study of the little house fly (*Fannia canicularis* (L.)) in Massachusetts, six natural enemies of this species and one of the latrine fly (*F. scalaris* (F.)) have been observed. The predators included the Gamasid mite, *Macrocheles muscae domesticae* (Scopoli);[2] the spider, *Salticus scenicus* (Clerck); the carpenter ant, *Camponotus pennsylvanicus* (DeGeer); and the yellow dung fly, *Scatophaga stercoraria* (L.) on *Fannia canicularis*. The parasites included *Empusa muscae* (Cohn)[3] snd the Pteromalid, *Pachycrepoideus vindemmiae* (Rond.)[4] on *F. canicularis* and the latter, *P. vindemmiae* on *F. scalaris*.

The mite, *M. muscae domesticae* (Gamasidae), has not been previously recorded as predaceous on *Fannia* spp. However, Hewitt (1914) reported an unidentified Gamasid mite, similar to *Dinychella asperata* (Berlese), attached to the venter of the abdomen of *F. canicularis* adults (West 1951). Phoresy was the suspected role of such mites until Pereira & deCastro observed nymphs of *M. muscae domesticae* preying on the eggs of the common house fly (Baker 1952).

In this study both nymphs and adults of *M. muscae domesticae* were found in the breeding media of *F. canicularis*, the nymphs readily preying on the eggs and first instar larvae of *F. canicularis*. The adult mites were frequently found firmly attached to flies by the insertion of their mouthparts through intersegmental membranous areas. As many as six mature mites have been observed attached to a single adult little house fly.

The entomophagous habits of the zebra spider *S. scenicus* are diverse and details concerning their diet are deficient. This common jumping spider was found inhabiting sides of buildings on several poultry farms. The grey and black stripes of this spider often blend with the background, enabling the spider to slowly approach within 1 centimeter of its prey. Arriving at this position, the spider remains motionless momentarily, then with a sudden leap, quickly captures and paralyzes its prey.

The workers of the common carpenter ant *C. pennsylvanicus* are predatory on adults of the little house fly. The prey were observed on apple leaves ingesting honeydew deposited by aphids. The ants traveled up the trunk of the tree to the aphid-infested leaves where they stalked and seized the unwary flies. With the prey in their mandibles, they descended the trunk of the tree and returned to their nests. This phenomena was observed

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[2] Identified by E. W. Baker, U. S. Department of Agriculture.

[3] Identified by E. A. Steinhaus, University of California.

[4] Identified by B. D. Burks, U. S. Department of Agriculture.

weekly on a neglected apple tree, from June 10 until July 8. After July 8, the aphid population diminished and honeydew deposits were no longer present to attract adults of *F. canicularis*.

While reporting the predaceous habits of Scatophagids on *Musca domestica*, Hewitt (1914) mentioned that *S. stercoraria* also attacked *F. canicularis*. On two occasions, this common coprophilous fly was observed preying on *F. canicularis* adults.

The Pteromalid, *P. vindemmiae* (Rond.) (=*dubius* Ashmead), was reported by Girault & Sanders (1910) as parasitizing several species of Diptera, but *Fannia* spp. were not among those listed. Accordingly, Peck in his compilations did not mention *Fannia* spp. as hosts of this Pteromalid (Muesebeck *et al.* 1951). In laboratory cultures, parasitization of *F. canicularis* pupae by *P. vindemmiae* was first noted in November, 1957. By the following March, parasitization reached about 70% in a culture of approximately 600 individuals. This parasite was also found in pupae of *F. scalaris*. Further observations on this parasite were discontinued upon discovery of Crandell's (1939) excellent biological and morphological account of this species.

During September 1957, large numbers of *F. canicularis* were observed to be infected with the fungus *E. muscae*, both in the field and in the laboratory. Graham-Smith and Hesse reported this fungus as affecting many adults in the fall months (West 1951). The occurrence of *E. muscae* on the little house fly is not a new record but is included here because of its seasonal manifestation in fly populations.

These observations serve to establish the following new host records of parasitism and predation: the mite *M. muscae domesticae* on *F. canicularis*, and the Pteromalid, *P. vindemmiae* on both *F. canicularis* and *F. scalaris*.

REFERENCES CITED

Baker, E. W., and G. W. Wharton. 1952. An Introduction to Acarology. The MacMillan Co., N. Y. 465 pp.

Crandell, H. A. 1939. The Biology of *Pachycrepoideus dubius* Ashmead (Hymenoptera), a Pteromalid parasite of *Piophila casei* Linné. Ann. Ent. Soc. America **32:** 632–54.

Girault, B. A., and G. E. Sanders. 1910. The Chalcidoid parasites of the common house fly or typhoid fly and its allies. Psyche **17(3):** 108–17.

Graham-Smith, G. S. 1919. Parasites of common flies. Parasitol. **11:** 347–84.

Hewitt, C. G. 1914. On the predaceous habit of Scatophaga; a new enemy of *Musca domestica*. Canadian Ent. **46:** 2–3.

Muesebeck, C. F. W., Karl V. Krombein, and Henry K. Townes. 1951. Hymenoptera of America North of Mexico. Synoptic catalog, U. S. Dept. Agric. Monogr. **2,** Washington, D. C.

West, L. S. 1951. The house fly, its natural history, medical importance and control. The Comstock Publishing Co., Ithaca, N. Y. 584 pp.

Role of Parasites and Disease in Controlling *Recurvaria milleri* Busck[1]

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Several attempts to control outbreaks of the lodgepole needle miner, *Recurvaria milleri* Busck (Lepidoptera, Gelechiidae), in high elevation lodgepole pine stands in Yosemite National Park have been made during the past 2 decades. Various insecticide tests have been conducted (Yuill 1942, Struble 1955), and pilot-plant aerial applications of sprays is well under way (Hall 1956, Trostle & Eaton 1958). Insecticidal control, however, generally provides only a temporary means of reducing the population density of insects. Consequently permanent regulation of the needle miner populations by natural factors should be sought in this high-value lodgepole pine cover. Exhaustive studies of entomophagous insects and of pathogens are important for planning biological control practices.

The study of the effects of disease on the population dynamics of the needle miner could also have a high prognostic value, enabling entomologists to foresee epizootics and thus limit insecticidal applications accordingly.

The existence of a wide range of entomophagous insects and of a disease among needle miner populations in the Yosemite National Park suggests the possibility of biological control of this pest. Among the 41 genera in 14 families of insects associated with the needle miner (Struble & Bedard 1958), 12 genera in 6 families have been reared from needle miner larvae and pupae. All belong to the order Hymenoptera:

Family	*Genus and Species*
Braconidae	*Meteorus* n. sp.
	Apanteles californicus Muesebeck
Ichneumonidae	*Scambus aplopappi* (Ashmead)
	Itoplectus behrensii (Cresson)
	Phaeogenes n. sp.? (probably)
Eulophidae	*Sympiesis* sp.
	Dicladocerus n. sp.
	Zagrammosoma americanum Girault
Encyrtidae	*Copidosoma* sp.
Pteromalidae	*Amblymerus* spp.
	Hypopteromalus sp.
Chalcididae	*Spilochalcis side* (Walker)

In 1951 a granulosis virus was isolated from needle miner larvae collected in the Yosemite National Park. These larvae were collected by J. H. McLeod, University of Vancouver, Vancouver, British Columbia, who was investigating the possibility of introducing parasite species in needle miner populations in Canadian lodgepole pine forests. In the course of his work, McLeod sent some needle miner larvae to the Insect Pathology Laboratory, Sault Ste. Marie, Ontario, Canada. A small percentage was found to be infected with a granulosis virus. Needle miner larvae were also sent directly from the Yosemite area to the Laboratory of Insect Pathology, Department of Biological Control, University of California, and were examined by E. A. Steinhaus, who also observed the presence of a granulosis virus. A record of the occurrence of this disease and an electron micrograph of the virus have been published (Steinhaus 1957).

The possibility of using this virus for the control of the needle miner outbreak has been investigated by the Laboratory of Insect Pathology, University of California. This work was done in cooperation with the California Forest and Range Experiment Station, U. S. Forest Service, and the National Park Service. Part of it was undertaken in 1952 and 1953 by C. G. Thompson (1953).

The occurrence of the virus disease in lodgepole needle miner populations in Yosemite National Park increased markedly in 1952: about 30% of the larvae were infected. In June 1953 the rate of morbidity was again determined in two localities of the Yosemite infestation under surveillance. Among needle miner larvae from the gap between Tenaya Lake and Cathedral Creek, mortality due to granulosis was between 30 and 50%. In the Conness Creek Basin mortality was about 30%. Needle miner populations in these areas then ranged from 20 to 45 per 5-inch twig. Notwithstanding the presence of the disease, a heavy moth emergence took place in 1953; numerous eggs were deposited, and countless larvae were established. At maturity of this and the next generation in 1955 and 1957 respectively, increasingly

[1] Accepted for publication January 5, 1959.

[2] Maintained at Berkeley, California, in cooperation with the University of California.

greater numbers of moths emerged, with the highest emergence on record in 1957.

Records of the incidence of parasitism were kept along with data on the needle miner biology. Larvae suspected of having died of virus infection were turned over to the Laboratory of Insect Pathology. These records revealed that estimated mortality resulting from insect parasitism ranged from 6 to 10% among maturing larvae, and nearly 40% among pupae. Diagnoses were not made on diseased or dead larvae from the 1953 to 1955 generation, but samples of larvae in the succeeding (1955 to 1957) generation were examined, revealing a very low incidence of the virus disease in a single locality: 2.9% at Soda Spring, Tuolumne Meadows. Samplings in late June and July 1957 showed no mortality caused by the virus, but histological preparations of larvae considered healthy at the time of fixing (June 25, 1957) revealed polyembryonic parasitism, presumably by a *Copidosoma* sp., in 24.9% of the examined specimens.

At present, 11 years after the discovery of this most recent outbreak of the lodgepole needle miner, parasites are the most important natural enemies. The disease has not as yet reached epizootic proportions, the morbidity rate remaining at an enzootic level. Granuloses, unlike polyhedroses, have been described often as diseases of low epizootic potential, although in some instances granulosis epizootics have been observed. Those insect parasites showing the greatest promise as control factors need to be studied in greater detail. Meanwhile, the possible evolution of the disease from its present enzootic level to one of epizootic proportions (owing to changes in the epizootic potential of the pathogen or in the environmental factors) should not be overlooked.

References Cited

Hall, Ralph C. 1956. The control of the lodgepole needle miner by the use of aerial application of DDT spray, Yosemite National Park—season of 1953. U. S. Forest Serv. California Forest and Range Expt. Sta. 7 pp. (Processed.)

Steinhaus, Edward A. 1957. New records of insect-virus diseases. Hilgardia **26**(7): 417–30.

Struble, G. R., and W. D. Bedard. 1958. Arthropod enemies of the lodgepole needle miner, *Recurvaria milleri* Busck (Lepidoptera; Gelechiidae). Pan-Pacific Ent. **34**(4): 181–6.

Struble, George R. 1955. Tests of new insecticides to control the lodgepole needle miner. U. S. Forest Serv. California Forest and Range Expt. Sta. 8 pp. (Processed.)

Thompson, C. G. 1953. Semi-annual report. Department of Biological Control, University of California. 2 pp. (Typewritten.)

Trostle, Galen C., and Charles B. Eaton. 1958. Tests with insecticides to control the lodgepole needle miner—1956 and 1957 seasons. U. S. Forest Serv. California Forest and Range Expt. Sta. 22 pp. (Processed.)

Yuill, J. S. 1942. Preliminary studies on the control of the lodgepole needle miner. Jour. Econ. Ent. **35**(1): 16–20.

Weather, Enemies and Natural Control of Insect Populations[1]

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The paper on weather, entomophagous species and natural control by DeBach (1958) in this *Journal* is a response to one of mine (Milne 1957a). Contrary to what DeBach states (p. 474), the latter paper (actually written early in 1956) was the basis of my talk at the Tenth International Congress of Entomology; and in reporting that talk the Montreal News Press (quoted by DeBach) misrepresented my thesis, as might be expected with a somewhat subtle subject. Such matters are, of course, irrelevancies. Since readers can compare Milne (1957a) and DeBach (1958) in detail for themselves, my rejoinder here can be confined briefly to four points. Incidentally, DeBach's criticism is in parts remarkably similar to Nicholson's (1958) which will be dealt with elsewhere.

1. In this question of natural control, I defined control (from the viewpoint of continuing existence of a population) as simply the unfailing arrest of increase and decrease somewhere (anywhere) short of the upper and lower extinction levels. DeBach does not refer to my definition and seems generally to be proceeding on the tacit assumption that control means maintaining a population at "economic" level. This unfortunately confuses the debate to some extent.

2. With regard to so-called "biological control," I argued that while an introduced factor (parasite or predator) may cause a lowering of the average level at which control of increase occurs it can only be partly responsible for the new (lower) value of the average since the latter results from action of both introduced factor and previously existing factors. DeBach maintains that the introduced factor is alone responsible for the new value of the average (p. 474). In support of this he says (p. 477): "When adequate insecticides are applied at suitable intervals to a pest population, that population can be reduced and maintained over an indefinite period at an average density much lower than would otherwise occur. . . . Most people would agree that the insecticide 'alone' or 'by itself' was the factor responsible for the maintenance of the population at the low average level obtained." But in the very next sentence he changes his proposition to one with which all people would agree, *viz.*: "In any event the insecticide was the one factor, the critical factor, responsible for the change in average population density from a high to a low level." Of course the insecticide changes (reduces) the level of population. But, obviously, at least some of the other effective environmental factors still continue to operate on individuals escaping the insecticide. Hence, although the insecticide may be largely responsible it can not be wholly responsible for the new value of the average level of control. The same is true of the introduced enemy. In a hypothetical arithmetical example (p. 475), DeBach calculates that 99% mortality in each generation is necessary "for control at an average given density." In that case, to maintain his thesis he would have to argue that the introduced enemy accounted for the entire 99%, which is ecologically untenable. Clearly, introduced factors may cause change in the average level of control but they can not be wholly responsible for the new value of the average. It need hardly be added that, so far as natural control is concerned, there is no parallel between (a) "adequate (chemical) insecticides . . . applied at suitable intervals" and (b) the action of enemies whether indigenous or introduced.

3. On the basis of Smith's valuable notion of some factors being density dependent, *i.e.*, having increasing intensity of action (percentage effect) with increasing density, I classified the effective environment into three kinds of factors briefly defined as follows (see also Milne 1957b, 1958): *With respect to any species X, and at any given environmental capacity for X,*

(i) the perfectly density dependent factor is one in which intensity of action is determined solely by density of X;

(ii) the imperfectly density dependent factor is one in which intensity of action is determined partly by density of X and partly by other variables which vary independently of the density of X;

[1] Accepted for publication February 6, 1959 not only in order to give the author fair opportunity for rebuttal but also because it may help capture reader interest in these problems and perhaps encourage reading of what DeBach, Milne, and others have written about the subject. A reviewer concluded that there is apparently no real conflict of views between DeBach and Milne so far as interpretation of data is concerned. Both have emphasized points where the other failed to make his meaning clear, usually because he felt that the reader's intelligence would be questioned if the interpretations were fully spelled out. Ed.

(iii) the density independent factor is one in which intensity of action is entirely independent of density of X.

My argument as to controlling properties was (in part) as follows: Mathematically, it can readily be shown that (A) only a perfectly density dependent factor can, by itself, unfailingly arrest increase of numbers and that (B), for control, the perfect density dependence must be geared to environmental capacity so that the arrest occurs at or below the limit of capacity. Clearly, then, neither enemies (being at best imperfectly density dependent) nor weather (density independent) can control by themselves since they do not even match up to the first condition (A). DeBach (like Nicholson 1958) has not absorbed the implications of imperfect density dependence when he asserts that this imperfection merely leads to variation in the level at which enemies control. Enemies do not have the properties for controlling by themselves at any level. Again, it is not at all clear whether he is arguing that a factor is wholly responsible or whether partly responsible for control. Thus one section (p. 476) is headed "Proof of Natural Control by Weather," suggesting that weather is going to be proved wholly responsible. But the first sentence after this heading reads: "Actual proof that weather is the *principal* factor responsible for regulation of an insect population at low densities may often be quite difficult to obtain" (the italics are mine), apparently reducing the proposition to proof that weather is only partly responsible. In this same section no distinction is made between two separate problems: (a) *spatial distribution*, or differences of numbers in space (places) at a given time; (b) *population dynamics*, or differences of numbers in time at a given place. Weather is only one factor in the complex of interacting factors setting a limit to the size which a population could attain *and continue to exist*. This limit can, of course, be higher in one place than in another. But in the question of natural control (a branch of population dynamics) we are concerned with what unfailingly prevents population from reaching or exceeding such limit in any given place, and this is certainly not weather alone.

4. In the paragraph straddling pp. 204–5 of my paper (1957a), from the beginning of the fourth sentence to the end, I am commenting *not* on ecological analyses but on statistical analyses. Unfortunately DeBach (like Nicholson 1958) has not noticed this. "Biological control" workers almost invariably present numerical data as unqualified means. I pointed out that means can be widely different numerically yet not significantly different statistically. In other words, there is room for doubt as to the validity of some conclusions based on unqualified means. And doubt is, of course, increased if an author (in the habit of presenting unqualified means) for once gives the complete sample data and shows that he claims means to be significantly different when they are not. It was to make the latter point that reference to DeBach's table 1 (1955) was made. This was purely and simply a question of significances of differences between means. The causes of the differences (apart from sampling error) were quite irrelevant, and I certainly did not imagine (cf. DeBach 1958, Nicholson 1958) that parasites or any other enemies were involved in the experiment. DeBach now states (p. 478) that he had in fact concluded "there were no differences between treatments." His actual conclusion in the paper (1955) was (a, b & c being interpolated by me): "It is evident from the data that, on the average, (a) the greatest scale increase and damage occurred on the untreated branches, or conversely, (b) that DDT residue on branches certainly caused no increase and (c) probably caused a decrease in scale populations as compared with untreated checks." This is at least a two (a and c) to one (b) decision that there was a significant difference between means, and it is not at all clear that (b) should not actually be taken as signifying the same as (a) and (c). "Biological control" workers could quite easily avoid criticism if, *with each mean*, they provided details of the number of sampling units involved (in this case, number of trees and units per tree) together with an estimate of the variance. This proper procedure would enable readers to examine rigorously not only the significance of differences but also the question of density dependence. In these respects, DeBach's table 1 (1958)—"Statistical reliability of California red scale population sample"—has little or no value.

SUMMING UP.—As noted in my paper, DeBach's field work does not prove that either enemies or weather effects can control population by themselves but merely that each can occasionally be mainly, though never wholly, responsible for control being at a low level.

REFERENCES CITED

DeBach, Paul. 1955. Validity of the insecticidal check method as a measure of the effectiveness of natural enemies of diaspine scale insects. Jour. Econ. Ent. **48**(5): 584–8.

DeBach, Paul. 1958. The role of weather and entomophagous species in the natural control of insect populations. Jour. Econ. Ent. **51**(4): 474–84.

Milne, A. 1957a. The natural control of insect populations. Canadian Ent. **LXXXIX**(5): 193–213.

Milne, A. 1957b. Theories of natural control of insect populations. Cold Spring Harbor Symposia on Quantitative Biology, **XXII**: 253–71.

Milne, A. 1958. Perfect and imperfect density dependence in population dynamics. Nature, **182**: 1251–1252.

Nicholson, A. J. 1958. Dynamics of insect populations. Ann. Rev. Ent. **3**: 107–36.

Tests of the Ability of *Reticulitermes flavipes* (Kollar) to Build Tubes Over Pine Wood Chemically Treated for Rot Control[1]

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It is apparently true that the ability of the eastern subterranean termite (*Reticulitermes flavipes* (Kollar)) to build tubes over timbers treated with certain fungicidal wood preservatives, although accepted as "common knowledge" by many professional pest control operators in the Southeast, is poorly documented in the literature—if at all. This is a point of some importance to architects, builders, loan organizations and the pest control industry, since it determines—in part at least—whether treated sills, floor joists and subflooring in a building can act as an effective barrier to protect untreated wood above from subterranean termites nesting in the ground below. For this reason, an effort was made to get some positive information on the question in laboratory experiments set up as follows:

A block of wood, partly eaten by termites, was tacked on top of a pedestal of treated wood about 1″×1″×6″. The pedestal was then stood on end in about 2 inches of dampened soil in the bottom of a museum jar 6 inches in diameter and 8 inches high. From 300 to 500 termites (workers, soldiers, and secondary reproductives) were then placed on the top block and allowed to crawl or drop to the soil below. A black sateen cover cloth was placed over the museum jar to exclude the light and the jar was left at room temperature.

After being placed in the jar with the termites, complete tubes had been constructed over an Osmose-treated pedestal in 9 days; over a pedestal cut from an old creosote-treated power-line pole in 12 days; over a freshly pressure-creosoted precut pedestal in 19 days; over a pedestal soaked for 1 week in a 2% solution of copper naphthenate in fuel oil in 27 days; and over a pedestal commercially-treated with Wohlman salts in 28 days. Photographs of four of the tubed-over pedestals are shown in figure 1.

[1] Accepted for publication February 2, 1959.

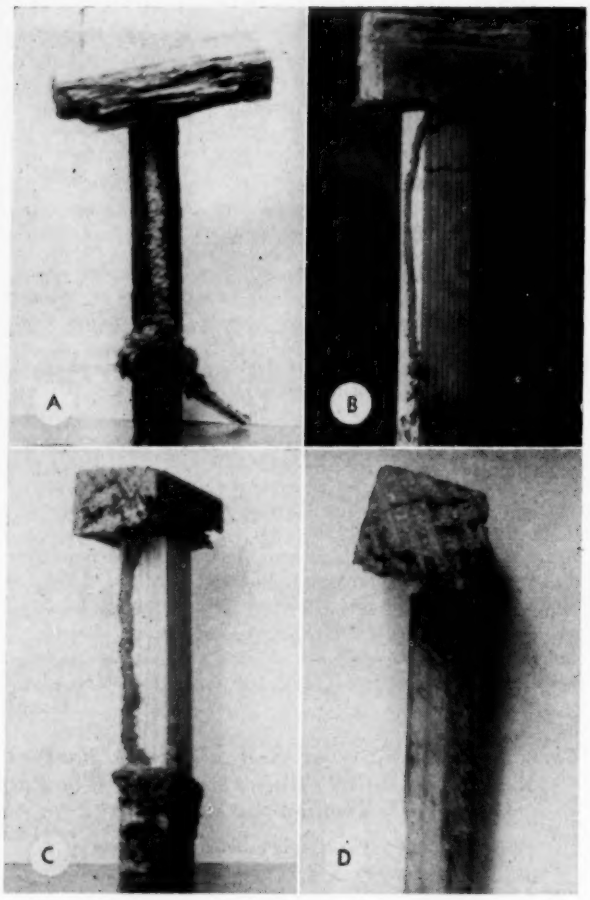

FIG. 1.—Chemically treated wood pedestals tubed over by the eastern subterranean termite. A—Treated with creosote, B—Treated with Osmose salts, C—Treated with Wohlman salts, D—Treated with copper naphthenate.

A pedestal soaked in a 2% solution of pentachlorphenol in fuel oil for several days and subsequently dried for 3 days is not yet tubed over after 8 weeks. Further experiments are now under way with pedestals treated with this and other wood-preserving chemicals.

These experiments demonstrate conclusively that the eastern subterranean termite can, under some circumstances at least, build tubes over lumber treated with certain of the common wood preservatives.

The Logarithmic Sprayer for Field-Screening Insecticides for Meadow Spittlebug Nymph Control[1]

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The maintenance of current recommendations for control of nymphs of the meadow spittlebug, *Philaenus leucophthalmus* (L.), on forage crops necessitates the yearly screening of newly developed insecticides. Often this is accomplished by the application of each new chemical at several concentrations in replicated plots. Subsequent counts which are made of the numbers of surviving nymphs on a predetermined number of forage stems or unit areas in each plot are compared with those made in untreated plots and plots sprayed with chemicals found, from previous tests, to give good control. A disadvantage of this screening method is the difficulty of precisely determining the limits of the effective concentrations of the various toxicants.

In an attempt to solve this difficulty, a Chesterford Logarithmic Spraying Machine[3] was tested in the spring of 1958. The sprayer is designed to deliver a logarithmically decreasing concentration of chemical in the spray as it moves along an experimental plot. This is accomplished by a continuous dilution of the insecticide with additional water in the tank during the time that the machine is in operation. Following calibration of the sprayer, and with a knowledge of the initial concentration delivered at the beginning of a plot, the concentration that will be delivered at any point along the swath within the plot can be calculated.

On May 15, 1958, six plots were laid out in a field of birdsfoot trefoil of the variety, Empire, located in Dryden, Tompkins County, New York; plot dimensions were 15 feet (one boom width) by 105 to 110 feet. Each of three insecticides, which were used as emulsions, was allocated at random to two of the six plots. Lindane and Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) were included as standards since they were expected, as a result of previous studies, to provide excellent control at rates as low as 0.1 pound of actual toxicant per acre. Guthion® (*O,O*-dimethyl *S*-(4-oxo-3*H*-1,2,3-benzotriazine-3-methyl) phosphorodithioate) which had not been tested previously in New York against meadow spittlebug nymphs, was regarded as an unknown.

A count of the number of nymphs of the meadow spittlebug per 25 stems was made at each 10-foot interval along each plot on June 5, 1958. The results are shown in table 1.

The results obtained in the two plots for each insecticide were remarkably similar and indicate that, although Guthion provided a high degree of control at rates as low as 0.23 pound per acre, it was not as effective as lindane or Thiodan. The use of the logarithmic sprayer is believed to have given a higher degree of precision for determining the limits of effective concentrations than would the use of a conventional sprayer delivering a single concentration to each plot. More precise comparisons can be made by narrowing the distance between sampling intervals in each plot, extending the lengths of the plots so that the decrease in effectiveness of the best materials can be observed, and including more than two replications of each insecticide.

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[2] The authors acknowledge the assistance of Stanford Fertig, Department of Agronomy, Cornell University, who furnished and operated the sprayer, and of R. L. Ridgway, who aided in the field work.
[3] Developed by Fisons Pest Control Limited, Felixstowe, England.

Table 1.—Numbers of meadow spittlebug nymphs per 25 stems taken at intervals along plots sprayed with a logarithmic sprayer.

Distance from Beginning of Plot (ft.)	Actual Toxicant (Lb./A)[a]	Nymphs in Each Plot at Indicated Distance[b]					
		Lindane		Thiodan		Guthion	
		1	2	1	2	1	2
30	0.43	0	0	0	0	0	0
40	0.31	0	0	0	0	0	1
50	0.23	0	0	0	0	0	1
60	0.16	0	0	0	0	1	4
70	0.11	0	0	0	0	3	5
80	0.08	0	1	0	0	2	3
90	0.06	1	1	0	0	5	10
100	0.04	1	0	0	0	4	14
105–110	0.03	1	3	3	1	8	8

[a] Initial concentration of 1.2 lbs. actual toxicant per acre applied.
[b] At 0, 10, and 20 feet, counts were zero and are not shown.

The use of the logarithmic sprayer for screening insecticides appears to be limited to those insects, such as nymphs of the meadow spittlebug, which have little lateral mobility during the test period. Obviously, any pronounced lateral movement could expose an insect to a concentration entirely different from that to which it was initially subjected.

The logarithmic sprayer merits the attention of anyone interested in screening insecticides for the control of the meadow spittlebug.

Effect of Seed Treatment with Insecticides on Rate of Seeding Wheat[1]

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Research work in Alabama with seed treatment of cotton (Robertson 1956) showed a reduction of plant stand in plots where treated seed was used. Since seed-treatment plots of wheat in field tests conducted in Oklahoma against the brown wheat mite, *Petrobia latens* (Mull.), and the false wireworm, *Eleodes* sp., had also shown a reduction in stand, a study was made to determine the cause of this reduction.

Triumph wheat seed was used in the tests against the brown wheat mite, and Comanche wheat seed in those against the false wireworm. Part of the Triumph seed was treated with 44% Thimet® (*O,O*-diethyl *S*-(ethylthio) methyl phosphorodithioate) on activated carbon at the rates of 18.2 and 27.3 ounces per 100 pounds. One portion of the Comanche seed was treated with 50% dieldrin wettable powder at 4 ounces per 100 pounds and 40% aldrin wettable powder at 7 ounces. The portions of seed not treated were used as checks. The tests were conducted immediately after treatment of the seed.

Germination tests, in which 100 seeds were placed on blotters with 10 seeds evenly spaced in each of 10 rows, were on both varieties of seed. The blotters containing the seeds were dampened with water and then placed in the germinator, where they were held for 2 weeks at 65° F.

Test weights were obtained on seed of both Triumph and Comanche wheat, with standard equipment. Since the test weight measures the degree of compactness, it thus offers an index to the seed's ability to flow.

The flowability test was made by determining the rate of seeding in a drill having a hopper over each outlet tube. This drill was provided with 13 outlets and a hand crank to give simulated seeding when the machine was in a stationary position. All seed samples were taken from the same source. To determine the variability in seeding rate of the various outlets, untreated seed was placed in 12 of the hoppers and the crank turned for 30 revolutions of approximately 1 second each. The seed was caught in ½-gallon ice-cream cartons placed under the outlets. The seed released from the odd- and even-numbered hoppers was then weighed and the mean weights were compared for rate of seeding.

The untreated seed was then placed in the odd-numbered and the treated seed in the even-numbered hoppers. The seed caught in the cartons after 30 turns was then weighed, and the mean weights were compared for treated and untreated seed. Three replications were made of each insecticide or dosage used.

The germination of both Triumph and Comanche wheat seed was the same. There was no significant reduction in the germination of treated seed as compared with untreated seed.

The results of the test weight and rate of seeding determinations are summarized in table 1.

The average reduction in test weight per ounce of formulation was 0.22% for Thimet at the 18.2-ounce rate and 0.19% at the 27.3-ounce rate. This would indicate a constant reduction in test weight as the rate of treatment increases. However, the average reduction in test weight per ounce of formulation was 0.73% for dieldrin and 0.59% for aldrin. Therefore, the test weight is influenced not only by the amount of the material used, but by the kind of formulation or toxicant.

For each 1% reduction in test weight the seeding rate was reduced by 3.2% with aldrin to 3.8% with Thimet (at the 18.2-ounce rate). Thus there appears to be a rather constant reduction in seeding rate as the test weight decreased. The lower test weights of treated, as compared with untreated seed, indicated a reduction in flowability. Actual runs of seed through a drill confirmed this observation.

REFERENCE CITED

Robertson, R. L. 1957. Effect of seed and soil treatment with systemic insecticides on cotton insects and on stand and yield of cotton. Proc. Assoc. Southern Agricultural Workers **54**: 147.

[1] Accepted for publication February 9, 1959.

Tedion Induced Sterility of *Tetranychus telarius* (L.)[1]

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Flik (1957), and Meltzer & Dietvorst (1957) reported that Tedion® (2,4,4′,5-tetrachlorodiphenyl sulfone) affects developing eggs in the ovaries of *Tetranychus urticae* Koch and *Panonychus ulmi* (Koch) after the females have taken up the chemical orally as well as by contact. The effect lasted for about 5 days after which viable eggs were laid.

In the following experiments an effort was made to determine if Tedion had similar effects on a normal strain of *Tetranychus telarius* (L.) reared on bean plants.

Bean plants were grown in 2-inch pots in the greenhouse until they were approximately 6 inches in height. Only the first two leaves were kept for experimentation. A ring of tanglefoot, approximately 1½ inches in diameter, was circumscribed on the

[1] Accepted for publication February 19, 1959.

Table 1.—Effect of seed treatment on test weight and rate of seeding of wheat seed.

Wheat Variety	Insecticide Formulation (Oz. per 100 Lb. of Seed)		Test Weight: Pounds per Bushel: Untreated	Test Weight: Pounds per Bushel: Treated	Test Weight: Per Cent Reduction Below Untreated	Rate of Seeding: Grams per Outlet: Untreated	Rate of Seeding: Grams per Outlet: Treated	Rate of Seeding: Per Cent Reduction Below Untreated
Triumph	Thimet 44%, carbon dust	18.2	58.0	55.7	4.0	202.9	172.1	15.2
		27.3	58.8	55.7	5.3	212.7	168.0	21.0
Comanche	Dieldrin 50%, WP	4.0	57.1	55.4	2.9	190.9	173.1	9.3
	Aldrin 40%, WP	7.0	57.1	54.7	4.1	195.2	169.6	13.1

Table 1.—Viability of spider mite eggs laid on untreated bean leaves by females that had previously been exposed to Tedion for a 24-hour period.

GRAMS OF ACTUAL CHEMICAL/1000 ML. WATER	AVERAGE PERCENTAGE HATCH FOR BOTH EXPERIMENTS
0.5	54.0
1.0	16.4
2.0	12.0
4.0	3.0
Untreated	96.3

upper surface of each leaf. Pieces of mite-infested bean leaves were placed within these tanglefoot rings and allowed to remain overnight. By the following morning most of the mites had crawled to the living plant tissue within the ringed leaf areas and the pieces of infested leaves were removed.

These plants were treated with 2 ml. of Tedion at four different concentrations of wettable powder formulations in water by means of a Peet-Grady DeVilbis sprayer, using a pressure of 12.5 pounds per square inch. Before spraying, each plant was placed at the bottom of a cylindrical spray tower 25 inches in height and 15 inches in diameter, with the spray nozzle directed toward the leaves at a distance of approximately 15 inches from them.

After the spray had dried the ringed leaves were clipped off and transferred to petri dish halves and held uncovered for 24 hours without water . Then fresh pieces of uninfested bean leaves were placed within the tanglefoot rings. In about 6 hours most of the mites had crawled onto the fresh leaves and these pieces were then transferred to the ringed area of new uninfested, unsprayed bean plants. These small pieces of leaf tissue dried rapidly and the mites soon crawled off them and began feeding and ovipositing. Twenty-four hours later all the crawling stages were removed from the ringed leaf area and the eggs deposited during this period were observed for viability. The number of eggs per replicate averaged 25. There were four replications for each treatment, including the check, which received only water. The entire experiment was repeated.

Daily counts of the number of eggs hatched were made for a 2-week period. However, all hatching occurred within 5 days. The results are given in table 1.

Exposure to Tedion for 24 hours caused females of *Tetranychus telarius* to lay a smaller percentage of eggs that were successful in hatching. As the dosage of Tedion was increased the percentage of eggs that hatched decreased. Perhaps this chemical will have broader uses in pest control as additional knowledge of its properties are discovered.

REFERENCES CITED

Flik, H. M. 1957. Results with Tedion VI8. Rept. XIVth Internatl. Horticultural Congress, 1955, 837–44.

Meltzer, J., and F. C. Dietvorst. 1957. Action of Tedion on eggs and ovaries of spider mites. Tijdschr. Plantenziekten 64: 104–10.

The Economic Effect of Aphidophagous Insects on Citrus in South China[1]

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The economic importance of aphids as pests of citrus appears to vary directly with the prevailing relative humidities (Quayle 1938). In regions of high humidities marked increases of aphid populations are seasonal and apparently dependent on the occurrence of new foliage. Heavy aphid infestations cause stunting of the new growth and characteristically deform the new leaves.

According to Clausen (1933) aphids on citrus in the tropical regions of Asia are at times very abundant and inflict injury comparable to that which occurs in the citrus-producing sections of the United States. The aphid species listed by Clausen as occurring on citrus in tropical Asia are *Aphis citricidus* (Kirk.), *A. gossypii*, Glov., *Myzus persicae* (Sulz.), and *Toxoptera aurantii* (Fonsc.) Clausen's personal observations, however, were limited to *T. aurantii* in India, Malaya, and the Dutch East Indies.

In view of this information the senior author was surprised to find, during a 9-month study of citrus insects in South China, that citrus aphids were very scarce and that the citrus tree was free of apparent aphid injury. This study, which ended in July 1954, was limited to British-controlled New Territories in Kwangtung Province.

The following discussion concerns the field observations and experiments undertaken in an attempt to determine the cause of this scarcity of citrus aphids.

It was observed that tree condition, temperature, and humidity appeared highly favorable for the reproduction and increase of citrus aphids, a situation in which the absence of aphids would indicate the presence of effective natural enemies.

Although in the region studied succulent new growth is continuously present on citrus during late winter and into early summer (beginning with the pummelo in January, the lemon in February, and the tangerine in March), aphid infestations are scarce and are found only in highly localized colonies on an occasional twig. During these months rainfall is relatively light, yet sooty mold in connection with such colonies is rarely seen. As the season progresses and becomes warmer, the number of such colonies increases in spite of increasingly heavy rainfall. This seems to be associated with the increased activity of aphid-attending ants. All the aphid colonies, however, eventually disappear in spite of ant activity.

Scarcity of aphids is attested by the fact that during the week ending March 11, 1954, three isolated citrus aphids were found after intensive searching. These were sent to California and yielded three adults of *Trioxys* sp.

In order to determine the suitability of citrus for the aphids, and to ascertain the natural enemies involved, a series of tests was initiated during the middle of February 1954.

The tests began by enclosing in an organdie sleeve-cage a branch of a pummelo tree bearing some new growth. At least one female of a black aphid was present on this branch. This female proved to be unparasitized because during the following 5 weeks a heavy population of this aphid entirely free of natural enemies developed within the cage. The leaves were badly curled and the large amount of honeydew produced resulted in the upper surfaces being covered with sooty mold. During this period the maximum air temperature was 68° F.

On March 16, 1954, the sleeve cage enclosing this artificial infestation was removed in order to expose the infestation to the attack of natural enemies. An examination within 2 days revealed the presence of several ovipositing natural enemies: a syrphid fly, a yellow braconid (probably *Trioxys*), and a black *Aphelinus* sp. Six days after exposure the entire aphid infestation, except for a few scattered individuals, disappeared. No evidence as to the causes of the cleanup remained on the infested branch because the parasitized aphids moved off in the search for crevices in which they died.

A series of artificial infestations of the black and green citrus aphids were established during April, May, and June. On April 25 a heavy infestation of a black aphid on a grapefruit branch was exposed by removing the enclosing cage. This infestation had been attended by numerous ants for some time. Within 3 hours following its exposure, the infestation was being attacked by adult *Aphelinus*. Oviposition by the parasite was observed. A sample of the infestation subsequently brought into the labora-

[1] Accepted for publication February 19, 1959.

tory, however, yielded no parasites, presumably because the parasitized aphids had migrated and disappeared into crevices. The infestation completely disappeared within 10 days.

Although the early artificial infestations had been unattended by ants, by the middle of May an increase in the highly localized ant-attended natural infestations occurred. The increase in ant-attended natural infestations was correlated with a gradual seasonal increase in daily temperatures and rainfall, the daily temperature range being from 37° to 70° F. during March and 80° to 90° F. during July.

An ant-attended natural infestation of the black citrus aphid was noted May 11 on two "water sprouts" on a lemon tree. A sticky barrier was placed around the base of each sprout, and during the next 48 hours this infestation was observed to be visited by two adults of a yellow braconid (probably *Trioxys*), and two species of probable hyperparasites, a black and a yellow cynipid.

As the season advanced with increasing temperatures and humidities, the proportion of hyperparasites and predators in relation to the primary parasites increased. Three species of coccinellids were observed feeding on the aphid populations. This relation appears to be correlated with an increase in the honeydew-collecting activity of ants. Hyperparasites such as *Aphidencyrtus*, and predators such as lacewing larvae, are less readily disturbed by the ants attending the aphids than are the primary parasites. It is noteworthy that ants were observed to attend the predatory lacewing larvae in the same manner that they attended the aphids.

Ants tend to perpetuate aphid colonies by cleaning up the honeydew in which young aphids may be trapped. They were also observed to collect the cast exuviae of aphids and place them together in "refuse dumps."

The new growth on tangerine is generally free of aphids. However, several natural colonies of the black aphid, which were observed on tangerine June 20, were soon eliminated by the action of the slate-grey "pill-bug" larvae of *Cryptogonus orbiculus* (Gyll.) and the jumping larvae of a cecidomyid. It is noteworthy that an adult of a minute blood-sucking fly was observed feeding on aphids.

Predation by the larvae of *Cryptogonus orbiculus* appears limited to aphids. They were found associated with the sugarcane aphid, *Oregma lanigera* Zhnt. (Lopez 1931). The species is oriental ranging from Ceylon to Japan (Kapur 1948). During the University of California Department of Biological Control 1948–51 program of introducing from China into California the natural enemies of citrus pests, four of the shipments contained live specimens of *C. orbiculus*.

Thirty shipments of parasitized citrus aphids were shipped by air mail from China to California during the period of February 1954 to May 1955. The junior author received these shipments and reared out of them the following endoparasites: 110 *Aphelinus chaonia* Walk., 250 *Aphelinus* sp. (near *toxopteraphidis* Kurdj.), 21 *Trioxys* sp., and 15 *Lipolexis* sp. One parasitized aphid collected in April 1955 from citrus at Shatin, N. T., yielded a primitive undescribed species of Aphidiinae. (The writers are indebted to their colleagues Harold Compere and E. I. Schlinger, and to C. F. W. Muesebeck, for the identification of the aphid parasites.)

The specimens of *Lipolexis* consisted of 9 females and 6 males. These reproduced for one generation on nearly mature *Aphis gossypii* infesting squash seedlings. On this host the life cycle was 14 days at temperatures between 78° and 80° F.

BIOLOGY OF *Aphelinus chaonia* WALK.—*A. chaonia*, which attacks the black citrus aphid, is a biparental species similar in appearance and habit to *A. mali* Hald. In California this species was propagated on *Aphis spiraecola* Patch., an important pest of citrus in North and South America. In the life-history studies of *Aphelinus* conducted in China, the artificially infested citrus branches were removed and the aphid infestations subjected to parasitization in the laboratory. The female readily oviposits in immature aphids and between ovipositions feeds on their body fluids. At 70° F. oviposition requires about 1 minute; the host-feeding process requires about 3 minutes for puncturing and about the same time for feeding (ingesting).

When about to oviposit, the parasite slowly approaches an aphid and takes a stance a short distance from it with antennae folded vertically to the plant surface. After a few seconds the parasite reverses its position, bends the distal half of its wings upward and forward against the other half, extends its ovipositor horizontally, and inserts it in the undisturbed aphid. During the entire oviposition process, the parasite touches the aphid only with its ovipositor. Seven days after the eggs are oviposited, the larval progeny are full-fed, completely filling the body cavity of the aphid. It is prior to attaining this condition that the aphid migrates, becoming negatively phototropic and positively thigmotropic. The full-fed larva of the endoparasite secretes a substance that fastens the blackened host body to the substrate.

Aphelinus sp. (near *toxopteraphidis*) has a similar biology and was produced in California in considerable numbers on *Myzus persicae* infesting potato sprouts. Propagation in the insectaries at Riverside and Albany from 1954–57 resulted in the colonization of 250 *Aphelinus chaonia* in Orange County against *Aphis spiraecola* on citrus, and 11,800 *Aphelinus* sp. (near *toxopteraphidis*) in Monterey and Ventura counties against *Myzus persicae*, *Aphis spiraecola*, and *Toxoptera aurantii*.

Proper evaluation of effectiveness of these colonizations was precluded by subsequent heavy incidence of disease among the aphids.

Six of the shipments from New Territories included 300–400 specimens of *Aphidencyrtus* sp. A note sent with the first shipment stated that this species might be secondary in habit. Subsequent tests under quarantine showed that such was the case. *Aphidencyrtus* oviposits in the live aphid while standing on its back "head to tail." The ovipositor is inserted in the *Aphis* for about 1 second. The full-fed hyperparasite fastens the aphid to the substrate and covers the inner wall of the aphid's body with a white silk. Usually, in the process of spinning this cocoon the body of the aphid is ruptured. The minimum life cycle of this hyperparasite at 80° F. is less than 18 days, that of its host (*Aphelinus* sp.) is 15 days.

REFERENCES CITED

Clausen, Curtis P. 1933. The citrus insects of tropical Asia. U. S. Dept. Agric. Circ. **266**, 35 pp.

Kapur, A. P. 1948. A revision of the tribe Aspidimerini Weise (Coleoptera: Coccinellidae). Trans. Roy. Ent. Soc. London **99**: 77–128.

Lopez, A. W. 1931. Entomology Department Ann. Rept. Res. Bur. Philippine Sugar Assoc. 1930–31, pp. 227–273.

Quayle, Henry J. 1938. Insects of citrus and other subtropical fruits. Comstock Publ. Co., Ithaca, N. Y. 583 pp.

A Chalcid[1] Parasitizing Spotted Alfalfa Aphids and Greenbugs in Kansas[2]

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Rapid and widespread infestation following the establishment of the spotted alfalfa aphid, *Therioaphis maculata* (Buckton), in the United States in 1954 has emphasized the necessity for in-

[1] *Aphelinus semiflavus* Howard, Family Eulophidae.

[2] Contribution No. 729, Department of Entomology, Kansas Agricultural Experiment Station, Manhattan. Accepted for publication February 25, 1959.

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creased investigations in biological control. The Agricultural Research Service of the United States Department of Agriculture and the University of California have been cooperating in a continued search for natural enemies in foreign countries, especially parasites of the aphid, and have been rearing them in large numbers. Mass parasite production of *Aphelinus semiflavus* Howard and other parasite species was initiated at Albany and Riverside, Calif., and at Moorestown, N. J.

The *A. semiflavus* released in Kansas originated in Israel and France, but were reared and shipped from the laboratory at Moorestown, N. J.[4] A total of 55,250 individual parasites was released in east-central and north-central Kansas, specifically: two sites in Riley county; three in Geary county; and one in Marion county. Releases were at eight different intervals from May 25 to June 18, 1956. A few specimens of *A. semiflavus* were recovered from the release sites during the fall of 1956.

Previously, however, this chalcid was collected as a native insect in Kansas. The hosts were listed as: *Anuraphis viburnicola* (Gill.); *Capitophorus rosarum* (Kltb.); *Chaitophorus viminalis* Monell; *Macrosiphum cornelli* Patch; *M. granarium* (Kby.); *M. sanborni* Gill.; *Myzus persicae* (Sulz.); *M. sp.* on *Aquilegia; Rhopalosiphum poae* (Gill.); *R. pseudobrassicae* (Davis); and *Toxoptera graminum* (Rond.) (Muesebeck *et al.* 1951).

Field collections of the spotted alfalfa aphid used for greenhouse cultures and later for biological studies became parasitized by *A. semiflavus* during midJuly, 1958. By August 17, the cultures were severely threatened by the chalcids. Collections were identified by B. D. Burks of the United States Department of Agriculture Insect Identification and Parasite Introduction Laboratories. It was stated that these specimens could not be associated, with certainty, with either the eastern North American or the Middle East strains. The collection contained both macropterous and brachypterous forms. These forms were previously described by Gahan (1924).

A second group of parasites on cultures of spotted alfalfa aphids was collected from another greenhouse September 16. These specimens contained *A. semiflavus* as well as an Encyrtid wasp, *Aphidencyrtus aphidivorus*. Burks stated that the latter species was thought to be a secondary parasite. According to Muesebeck *et al.* (1951) this species has not been reported previously from Kansas.

Cultures of the greenbug, *Toxoptera graminum* (Rond.), in an insectary had become heavily parasitized by *A. semiflavus* during September and October. The parasites presumably had been introduced by parasitized spotted alfalfa aphids on alfalfa cuttings.

The above three infestations gradually increased in their respective greenhouses and insectaries and later threatened to completely destroy both spotted alfalfa aphid and greenbug cultures.

It is thought that the species of *A. semiflavus* native to Kansas is of the eastern North American strain. At present authorities are unable to differentiate between the eastern North American and the Middle Eastern strains. Therefore, there is no positive way of knowing whether the infestations reported here were caused by the native species or by a buildup of the released species of the parasite.

REFERENCES CITED

Gahan, A. B. 1924. Some new parasitic Hymenoptera with notes on several described forms. Proc. U. S. Natl. Museum 65, Art. 4, pp. 1–23.

Muesebeck, C. F. W., Karl V. Krombein and Henry K. Townes. 1951. Hymenoptera of America north of Mexico. U. S. Dept. Agric. Agriculture Monograph No. 2.

[4] The efforts and assistance of James K. Holloway, Albany, California, and D. W. Jones, Moorestown, New Jersey, are appreciated.

Rapid Collection of Insect Blood[1]

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The collection of blood from insects for biochemical and physiological studies has always been a time-consuming process. Withdrawing blood by means of capillary tubing yields, at best, microliter amounts and only a fraction of the total volume present can be removed. Thus, manual expression of blood from the cut ends of antennae and legs of American cockroaches (*Periplaneta americana*) (L.)) was used by Sternburg & Kearns (1952). The blood was frozen as it was collected to prevent clotting and darkening. By this method one man could collect about 2 ml. of blood a day at the rate of 50 female or 100 male American cockroaches per ml.

During an investigation of biochemical changes in the blood of DDT-poisoned insects, it became necessary to collect comparatively large samples of cockroach blood. For this purpose a method was developed involving low speed centrifugation of cockroaches which has the advantage of rapidly yielding a large percentage of the hemolymph present.

To prevent contamination of the blood by the contents of the digestive tract, the mouth and anus must be sealed. This is done by dipping the lower part of the head and the tip of the abdomen into melted paraffin at a temperature between 65° and 100° C. The paraffin solidifies quickly around the mouth parts and the terminal abdominal processes and, due to the irregular contours of these structures, adheres to form an effective seal. One dipping is sufficient since it is unnecessary to build up a heavy layer of paraffin. Following sealing of the body openings each leg is severed across the coxa, the antennae clipped short and the cockroach placed head down upon a perforated disc inserted about 40 mm. below the top of a centrifuge tube. One tube can accommodate 8 to 10 cockroaches at a time. The tubes are placed in a centrifuge and spun for 5 to 10 minutes. The blood is thrown down through the disc as a clear serum with the cells massed in a layer on the bottom of the tube. The cell-free serum can be decanted off or, by gentle swirling, the cells can be resuspended in the serum.

The centrifuge used was an International Clinical model, with a four-place angled head holding four 50-ml. metal shields. The tubes were 40-ml., conical, ungraduated Pyrex brand glass centrifuge tubes with a heavy wall and an inside diameter of 25 mm. The centrifuge setting for optimal yield of blood was about 2200 r.p.m., giving a relative centrifugal force of about 650 X gravity. At this setting most of the blood was collected after 5 minutes, although we usually centrifuged 10 minutes to insure sedimentation of the hematocytes. Twenty adult females gave about 1 ml. of blood while 20 adult males yielded about 0.5 to 0.7 ml. of blood.

The tubes used for blood collecting were prepared in the following manner. The tubes were softened by heating them in an oxygen-gas flame and four slight indentations were made with a pointed tool at equal distances around the tube wall and about 40 mm. from the top of the tube. These concave impressions served as supports for a plastic disc, through which small holes were drilled to allow blood to run into the tube.

By using a six-place angled head with six heavy duty, 12-ml., conical graduated Pyrex brand glass centrifuge tubes, it was possible to collect blood from individual cockroaches. The 12-ml. tubes were prepared in a different manner than the larger ones, by holding them horizontally and rotating them evenly in an oxygen-gas flame placed about 40 mm. from the top of the tube. The tube wall softened and gradually thickened, forming an internal constriction of uniform circumference. Careful manipulation prevented any change in the shape of the external tube wall. A small perforated plastic disc was placed in the tube and

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supported by the internal constriction. An individual cockroach was placed head down upon this disc prior to centrifugation.

Since it requires only 20 minutes to collect about 2 ml. of blood, one man can easily collect 20 ml. of cockroach blood in 4 hours. Blood can be collected within a range from 2000 to 2300 r.p.m., but attempts to decrease the time of centrifugation with greater velocities result in frequent rupture of internal body structures, contaminating the hemolymph with foreign materials. Dissection of cockroaches following centrifugation revealed little or no hemolymph remaining, and at the specified r.p.m. no rupture of the digestive tract could be observed.

This technique was developed for the American cockroach, but it is undoubtedly adaptable to studies on hemolymph from various insects. In such cases, similar sealing of the body openings with paraffin followed by clipping of the legs close to the body, would probably be the appropriate procedure. The optimal velocity of centrifugation for different insects would, of course, be determined empirically.

REFERENCE CITED

Sternburg, J., and C. W. Kearns. 1952. The presence of toxins other than DDT in the blood of DDT-poisoned roaches. Science 116: 144–7.

Sheep Ked Control with Organic Phosphorus Compounds[1]

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The sheep ked (*Melophagus ovinus* (L.)) is a wingless parasitic fly, which spends its entire life on the host. It is found in all parts of the world where sheep are raised. The larvae develop inside the female and are deposited or glued to the fleece. Adults emerge in 3 to 4 weeks.

The sheep ked is not a difficult pest to control. Pyrethrum and rotenone preparations were rather widely used until about 1945. When the chlorinated hydrocarbon insecticides appeared, a number of them were found to be highly effective. Recent tests in western Oregon indicate that some of the organic-phosphorus compounds are exceptionally good against this fly.

Ked populations are estimated by parting the fleece by hand and counting the keds seen at each part, but the manner and extent in which this is done has varied. Nelson & Sten (1953) studied four of the better-known methods and concluded that there was no significant difference between them.

The authors made partings in five areas on each side of an animal—the neck, shoulders, side (two places), and crotch. The distances between these areas were as nearly equal as possible. From 10 to 15 animals were examined in each flock or test group before and at various times after treatment. The data are based on examinations of the lambs only, since some of the ewes had been clipped just prior to treatment.

The insecticides were applied with a power sprayer at 250 to 300 pounds' pressure. In 1957 the tests were conducted in January through May at the rate of 2 quarts of spray for each ewe and 1 quart for each lamb. In 1958 they were made during April, May, and June, with 2 quarts per animal on both ewes and lambs.

The results of the 1957 tests are presented in table 1. Korlan® or Dow ET-57 (*O,O*-dimethyl *O*-(2,4,5-trichlorophynyl) phosphorothioate) and malathion were tested at concentrations varying from 0.1 to 1.0%, and Bayer 21/199® or Co-Ral® (*O*-(3-chloro-4-methylumbelliferone) *O,O*-diethyl phosphorothioate) at 0.25 to 0.75%. Korlan was tested both in an emulsion and a suspension. Although very good control was obtained with all these materials, Korlan gave the best results and malathion was slightly more effective than Bayer 21/199. No difference was evident between emulsions and suspensions of Korlan.

Table 1.—Results of 1957 spray tests with organic phosphorus insecticides for the control of the sheep ked.

Insecticide		Number of Animals	Number of Keds per Animal	Per Cent Control After (Weeks)		
Concentration (%)	Formulation (%)			2	4	8
Korlan						
0.1	50 EC	60	5.2	100	—	—
.25	25 WP	40	8.3	100	100	100
.5	50 EC	86	24.3	100	100	—
	25 WP	56	11.0	100	—	100
.75	50 EC	30	10.3	100	100	—
1.0	25 WP	56	14.2	100	—	100
Malathion						
0.1	57 EC	100	5.3	100	—	—
.25	30 EC	150	15.4	97	—	—
		100	3.7	100	100	100
.5	57 EC	75	9.8	99	—	100
.75	30 EC	31	7.9	100	—	100
1.0	57 EC	75	8.4	100	—	99
Bayer 21/199						
0.25	25 WP	35	10.5	98	100	—
		38	22.2	94	—	99
.5		85	6.8	100	100	100
		43	19.5	95	—	97
.75		19	10.7	100	100	—

In 1958 seven organic-phosphorus insecticides were tested at the low concentration of 0.1%, and DDT was included for comparison. Korlan, Delnav (Hercules AC 528), Bayer 21/199, and Dowco 109® (*O*-(4-*tert*-butyl-2-chlorophenyl) *O*-methyl methylphosphoramidothiate) gave complete control. Good results were also obtained with dicapthon and malathion, but dicapthon caused some staining of the wool. Dipterex® (*O,O*-dimethyl

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Table 2.—Results of 1958 tests against the sheep ked with sprays containing 0.1% of various organic phosphorus insecticides.

Insecticide	Number of		Per Cent Control After (Weeks)	
	Animals	Keds per Animal	2	6
Korlan, 24% EC	83	18	100	100
	150	17	100	100
25% WP	155	19	100	100
Delnav,[a] 47% EC	60	9.6	100	100
	63	5.3	100	100
Bayer 21/199, 25% WP	57	14	100	100
	122	10.6	100	100
Dowco 109,[b] 25% WP	86	9.0	100	100
Dicapthon, 25% EC[c]	100	9.3	100	99
	92	4.8	96	96
Malathion, 57% EC	89	27	99	95
	230	8.8	100	79
Dipterex,[d] 50% water-soluble	68	9.0	83	85
DDT (check), 75% WP	43	23	97	96
	195	15	76	93

[a] Delnav® or Hercules AC-528 (2,3-*p*-dioxanedithiol *S,S*-bis(*O,O*-diethyl phosphorodithioate).

[b] Dowco 109® (Phosphoramidothioic acid, methyl-*O*-(4-*tert*-butyl-2-chlorophenyl)*O*-methyl ester).

[c] Stained wool yellow.

[d] Dipterex®(*O,O*-dimethyl 2,2,2-trichloro-1-hydroxyethylphosphonate).

2,2,2-trichloro-1-hydroxyethylphosphonate) was less effective, but this may have been partially due to the formulation used.

That the phosphorus compounds as a group are highly effective against the sheep ked is clearly indicated in the fact that six of the seven materials tested were at least as effective as DDT. However, their relative cost and effectiveness when used at concentrations recommended for general use have not yet been determined.

Reference Cited

Nelson, W. A., and S. B. Sten. 1953. Note on evaluating populations of the sheep ked, *Melophagus ovinus* (L.) *Diptera: Hippoboscidae*, on feeder lambs. Canadian Jour. Agric. Sci. **33**(6): 620–1.

Tests Comparing Insecticides for the Control of Thrips on Spinach[1]

James A. Harding[2]

The presence of insect bodies or pieces thereof in canned goods have been an important problem in the processing industry for many years and are surely detrimental to the fresh market producer. Walton (1950) reported that 29.1% of Oklahoma's green crop acreage was lost due to the presence of insects in the produce during the period of 1946 to 1949. Austin (1952) stated that the spinach pack in Arkansas in 1950 was reduced from an estimated 3,000,000 to 100,000 cases due to the presence of "stem worms." Even though the number of insects on green crops may be so small that yields are not affected, marketing of the crop is definitely hindered or prohibited by law. The grower of green crops must secure highly efficient control and cannot afford to delay the time of harvest very long.

Thrips were noted building up on spinach plants in the Winter Garden area of Texas during the early part of December, 1958. By the middle of January, 1959, the insects ranged from 4 to 10 individuals per mature plant and might have seriously interfered with the sale of the crop. Two insecticidal screening tests were designed to evaluate the more recently developed insecticides for the control of the insect. A toxicant with a relatively short residual duration was desired.

The primary object of this paper is to report thrips as a contamination factor on spinach. Previous literature has dealt only with aphids, leaf miners, seed-corn maggots (*Hylemya cilicrura* (Rond.)), loopers, and corn earworms (*Heliothis zea* (Boddie)) on spinach. The secondary purpose is to give the results obtained with 16 insecticides for the control of the thrips.

During the tests herein reported, plants observed with an infestation of 20 to 26 thrips showed no apparent physical damage that could definitely be attributed to the presence of these insects. Some inward folding of the young, cluster leaves was observed, however. Most of the adults and all of the larvae were found in the leaf cluster before, during, and after the tests. No larvae and only two adults were found on the center, developing leaves from the 2,088 plants examined in evaluating these treatments. The principal species of thrips involved was *Frankliniella occidentalis* (Pergande).

Materials and Methods.—These tests were made on 2½- to 3-months old Dark Green Bloomsdale spinach during January of 1959. Plots in the first experiment were treated on the 13th with the second experiment being treated on the 14th. The spinach plants averaged 7½ inches in diameter with fairly compact leaf clusters. Furrow irrigation was used with the rows located on beds with 18-inch centers. Sprays in both experiments were applied on warm, humid days. Temperatures at spraying time ranged above 60° F. with nighttime temperatures during the tests in the 40's. Heavy dew followed application in both tests

The design of each test was a randomized block having each treatment replicated six times on experimental plots four rows wide and 25 feet long. Two rows per plot were treated which left one guard row on each side of each treated area. The treatments were evaluated by counting thrips on six randomly selected plants per plot. This was done early in the morning so the thrips would be partially inactivated. Counts were made at 1-, 3-, 7-, and 10-day intervals following application or until most of the insecticides became ineffective. The average number of thrips per plant in the untreated control plots is shown in the tables. Data were statistically analyzed for sources of variance by applying the F test and a multiple range test outlined by Duncan (1955) to evaluate differences among treatment means.

Treatments were applied as sprays by one nozzle directly over the row at the rates indicated in the accompanying tables. Thirty pounds of pressure per square inch delivered 5 gallons of liquid per acre.

Table 1.—Chemical control of *Frankliniella occidentalis* (Pergande) on spinach in 1959.

Insecticide	Pounds Active Ingredient per Acre	Per Cent Control[a] (on Days after Application) 1	3	7	10
	Experiment 1				
Malathion	1.00	99	100	95	78
Parathion	0.50	99	99	98	95
Dicapthon	1.00	98	100	93	75
Diazinon	0.50	79	97	79	47
Guthion	0.50	99	100	95	78
Dylox	0.50	93	99	80	54
Ethion	0.50	74	96	77	51
Thiodan	0.75	94	93	82	64
Control[b]		12.9	14.6	12.8	13.1
	Experiment 2				
Dibrom	0.50	94	94	63	
Foliafume[c]	0.20	79	70	26	
Trithion	0.75	81	88	61	
Sevin	1.00	74	83	32	
Dow ET-57	0.75	88	82	51	
Phosdrin	0.50	98	98	84	
Perthane	1.00	97	94	77	
Pyrexel W.P.[d]	1.10	92	77	46	
Control[b]		11.9	9.5	18.6	
		1	3	7	

[a] Based on untreated control plots.
[b] Mean number of thrips per plant.
[c] 57.2% oils, cube extractives, rotenone, and pyrethrins.
[d] 2% pyrethrins and 20% n-octyl sulfoxide of isosafrole.

Results and Discussion.—The first experiment is summarized in table 1. Considerable outer-leaf burn was apparent in all plots treated with dicapthon 2 days after treatment. This would rule out its local use in this formulation or under prevailing weather conditions on spinach. An analysis indicated Diazinon® sampled as Dylox® (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothioate) and ethion were inferior to the other toxicants 1 day after treatment. The 3-day readings showed no differences among the insecticides used. Seven-day counts indicated Diazinon, ethion and Thiodan® (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide) gave inferior control of thrips. The 10-day reading showed that parathion was still highly effective with malathion, dicapthon, and Guthion® (*O,O*-dimethyl *S*-(4-oxo-

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3*H*-1,2,3-benzotriazine-3-methyl) phosphorodithioate) giving control superior to the remaining insecticides.

Results of the second experiment are also shown in table 1. Analysis of recorded data 1 day after treatment indicated that Dibrom® (*O,O*-dimethyl-*O*-(1,2-dibromo-2,2-dichloroethyl) phosphate), Phosdrin® (1-methoxycarbonyl-1-propen-2-yl dimethyl phosphate, 60% technical) and Perthane® (1,1-dichloro-2,2-bis(*p*-ethylphenyl)ethane) were superior to the other insecticides but that Trolene® or Dow ET-57 (*O,O*-dimethyl *O*-(2,4,5-trichlorophenyl phosphorothioate) and Pyrexel W.P. gave good control. Three days after application, an analysis showed that Phosdrin was the most effective toxicant but Dibrom, Perthane, and Trithion® (*S*-(*p*-chlorophenylthio)methyl *O,O*-diethyl phosphorodithioate) were also effective. Sevin® (1-naphthyl *N*-methylcarbamate) and Dow ET-57 were superior to the remaining treatments. Seven-day counts indicated that Phosdrin and Perthane were superior to the other insecticides for thrips control even though these treatments had an average infestation of three to four thrips per plant by this time.

On the basis of these tests, it would appear that five phosphates and one chlorinated hydrocarbon were effective as thrips clean-up sprays on spinach. They are malathion, parathion, Guthion, Phosdrin, dicapthon in another formulation, and Perthane.

REFERENCES CITED

Austin, H. L. 1952. Canned spinach, worms and politics. Quart. Bull. Assoc. Food & Drug Officials **16**: 17–23.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics **11**: 11–42.

Walton, R. R. 1950. A progress report on the control of insects infesting green crops. Oklahoma Expt. Sta. Mimeo. Circ. **M-193.**

Effectiveness of Some Newer Insecticides for Control of *Macrosiphum pisi* (Harris) and *Epilachna varivestis* Muls.[1]

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Insecticides recommended in Maryland for the control of pea aphid *Macrosiphum pisi* (Harris) and insects attacking snap beans are at present satisfactory, but because insects may develop resistance to specific chemicals it was thought desirable to evaluate some of the newer poisons, should occasion arise for their need. Three small-plot field experiments, two on peas and one on snap beans, were carried out in 1958 with several insecticides, including Diazinon®, (*O,O*-diethyl *O*-(2-isopropyl-4-methyl-6-pyrimidinyl) phosphorothiate), malathion, Dibrom® (*O,O*-dimethyl-*O*-(1,2-dibromo-2,2-dichloroethyl) phosphate, an experimental insecticide furnished by the California Spray-Chemical Corporation, Moorestown, New Jersey), dicapthon, Trithion®, (*S*-(*p*-chlorophenylthio)methyl *O,O*-diethyl phosphoro-dithioate), phosphamidon, Thiodan®, (6,7,8,9,10,10-hexachloro-1,5,5*a*,6,9,9*a*-hexahydro-6,9-methano-2,4,3-benzodioxathiepin-3-oxide), dimethoate, and Am. Cyanamid 18,706 (*O,O*-dimethyl *S*-(*N*-ethylcarbamoylmethyl) phosphorodithioate, experimental insecticide furnished by the American Cynamid Company, New York).

PROCEDURE.—In Experiment 1, nine insecticides, as shown in table 1, were applied to Thomas Laxton peas. All treatments were replicated four times in randomized block design on plots 5×80 feet. All insecticides, in the emulsifiable form, were mixed with water and applied at the rate of 25 gallons of finished spray per acre. Spraying was done on May 27 with recommended broadcast equipment (Ditman & Burkhardt 1952). Aphid populations were estimated by the sweep method just before treatment, and 2 and 10 days after treatment. Plots were harvested and yields recorded on June 8. At the time of treatment plots averaged 35 aphids per sweep.

Table 1.—Insecticides applied in Experiment 1 for control of pea aphid, average number of aphids per sweep for all plots 2 and 10 days after treatment, and average yield of peas per plot for each treatment.

Insecticide	Pints per Acre	Pounds Active Ingredient per Gal.	Aphids per Sweep		Average Yield (Lb./Plot)
			May 29	June 6	
Dimethoate	2	4	1.0	1.2	18.7
Dimethoate	1	4	.0	2.2	19.0
Am. Cyanamid 18,706	2	2	.5	2.7	17.7
Phosphamidon	2	4	.5	2.0	19.0
Malathion	2	5	.5	2.7	18.8
Dicapthon	2	4	.2	5.5	18.3
Thiodan	2	2	.0	2.0	18.8
Dibrom	1	8	.7	2.5	18.6
Diazinon	2	2	.5	3.2	20.0
Untreated			9.0	17.7	18.5

Table 2.—Insecticides applied in Experiment 2 to peas, pre- and posttreatment population estimates.

Insecticide[a]	Pounds Active Ingredient per Gal.	Aphids per Sweep	
		June 24	June 25
Trithion	4	85	0
Dimethoate	4	225	0
Am. Cyanamid 18,706	2	113	0
Phosphamidon	4	124	0.5
Malathion	5	126	0
Untreated		102	105

[a] Applied at 2 pints of emulsion concentrate per acre.

In Experiment 2 consisted of the application of five insecticides, as listed in table 2, to drill-width plots of Pride peas. Sprays were applied in the same manner as in Experiment 1 on June 24 at which time aphids averaged 129 per sweep on all plots. To minimize the effect of spray drift, treated plots were separated from each other by two untreated plots. Results are based on sweep counts made immediately before treatment and 48 hours after treatment.

In Experiment 3, four insecticides, shown in table 3, were applied to 2-row, 0.008 acre plots of Top Crop beans in randomized blocks replicated four times. All insecticides were applied in 25 gallons of water per acre with a recommended type row-crop sprayer (Burkhardt & Ditman 1956) on June 24 and July 7. Results are based on yields and extent of plant and pod injury. In making plant-injury estimates, rows were divided into twenty 3-foot intervals, and the number of intervals showing adult or larval Mexican bean beetle (*Epilachna varivestis* Muls.) damage was recorded. These observations were made July 14, one week

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Table 3.—Insecticides applied to snap beans and reduction of feeding injury to foliage and fruit.

Insecticides[a]	Mexican Bean Beetle Damage/ Plot	Yield (Lb./Plot)	Per Cent Pods		
			Damaged by Chewing Insects	With Scars	
				July 21	July 30
Malathion	1.2	29.3	0	0.2	2.2
Dimethoate	.9	30.8	0	.2	2.0
Am. Cyanamid 18,706	1.2	27.0	0	1.2	3.0
Phosphamidon	.1	31.5	0	.5	2.0
Untreated	15.6	25.3	37.5	.2	9.2

[a] All insecticide concentrates applied at 2 pints per acre.

before the first harvest. Extent of pod damage was estimated on 100 pod samples from each plot at each of 2 pickings. Samples from each plot at each harvest were processed and canned for flavor evaluation.

RESULTS AND DISCUSSION.—In Experiment 1, all insecticides used performed well against the pea aphid (table 1). Two days after application of insecticides the number of aphids per sweep on the treated plots ranged between zero and one, with the control plots averaging nine. There were no differences between yields of treated and untreated plots. The low aphid counts in the untreated control plots of Experiment 1 after treatments were applied is attributed to insecticidal drift, indicating that for accurately evaluating highly effective aphicides plots should be sufficiently distant from each other to minimize effect of drift. Experiment 2 was immediately carried out, in which only every third plot in the field was treated. Trithion, phosphamidon, malathion, dimethoate, and Am. Cyanamid 18,706 gave highly satisfactory reductions of aphids (table 2), the counts ranging from 0 to 0.5 per sweep in the treated plots compared with 105 in the untreated control.

In Experiment 3, results obtained with the three systemic insecticides, phosphamidon, dimethoate, and Am. Cyanamid 18,706, compared favorably with malathion for control of the Mexican bean beetle in reducing feeding injury on pods and plants and for reducing injury and shallow scars on pods, the causes of which were unknown. Yields were increased by all insecticidal treatments, though not significantly (L.S.D. at 5 % level) by 18,706 (table 3). No significant off-flavors were detected on beans from any treatment.

REFERENCES CITED

Ditman, L. P., and G. J. Burkhardt. 1952. Further experiments on pea aphid control. Jour. Econ. Ent. **45**(5): 880–1.

Burkhardt, G. J., and L. P. Ditman. 1956. Improved spray boom for row crops. Univ. Maryland Agric. Expt. Sta. Misc. Publ. **269**, 9 pp.

A Unique Culture Difference Between Two Strains of House Flies[1]

JOHN L. ZAHARIS[2] and C. C. ROAN,[3] *Kansas State University, Manhattan*

A violet color in cellucotton watering pads placed in house fly (*Musca domestica* L.) cages under laboratory culture was observed in this laboratory for the first time October 15, 1958. Spontaneous development of this color and its spread over the surface of watering pads is a common occurrence in the fly rearing room (which has a temperature of approximately 25° C.) whether an insecticide resistant strain of flies designated as CAL is present or not. The violet color does not appear spontaneously nor does it spread after inoculation in the presence of an insecticide susceptible strain of flies designated as KUN (Plate 1). In the absence of violet color, the watering pads routinely develop a butter-yellow color after approximately 4 days' exposure to flies.

Bacterial isolations from the violet watering pad include a violet, yellow, and colorless colony on starch agar media at 20° C. Isolations from the yellow cup include a yellow, greenish-yellow, and colorless colony on the same media at 20° C.

Inoculation of fresh cellucotton in a cotton stoppered container with violet isolate resulted in development of violet color in the fresh preparation.

All attempts to extract the violet color from cellucotton have proved unsuccessful. The color will bleach with Chlorox. Color may be produced on Kleenex, and various colored tissues, but not on filter paper or absorbent fiber-cotton.

Further investigations of the relationships between these colors and various strains of house flies are in progress at present, as well as the determination of the species of bacteria isolated from the cups.

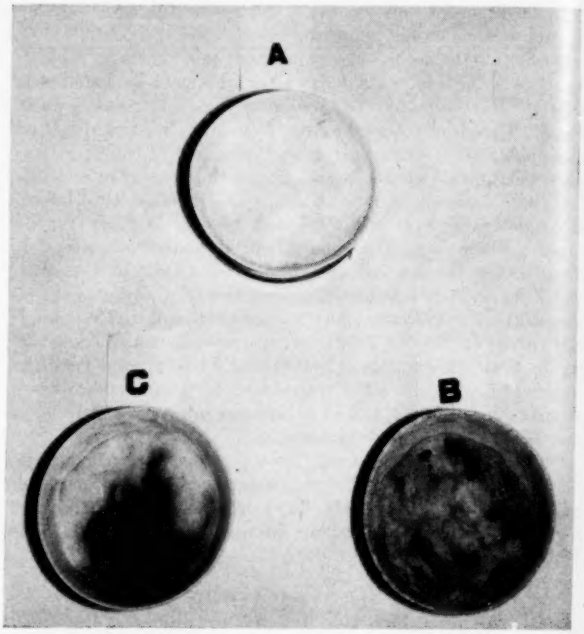

PLATE 1. Watering cups demonstrating the color phenomena observed in fly rearing cages. A. A freshly prepared cup of white cellucotton. B. A cup which has become yellow, taken from a cage of insecticide-susceptible flies (dark objects are empty pupal cases). C. A cup of cellucotton taken from a cage of parathion-resistant flies, showing the violet color spreading on the white cellucotton.

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[2] Graduate Research Assistant.

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Results with Cockerels for House Fly Control in Poultry Droppings[1]

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Control of flies in the manure is required for a small flock of chickens maintained on this campus for experiments in the control of ectoparasites of poultry. The chickens are housed in wire cages off the ground. We did not want to use general applications of insecticides to control flies since part of the birds are used as hosts for colonies of various insects and mites and other birds are used in preliminary screening tests of new chemicals. On the other hand, we desired a less expensive method than that of removing the manure at intervals of less than a week.

Young chicks instinctively scratch and search every bit of surface within their reach constantly and industriously looking for food. If growing chicks were allowed to scratch in the droppings under the wire cages, would their activities control flies? If they did, what management practices would be useful in obtaining optimum performance?

MATERIALS AND METHODS.—The experimental poultry house is divided into two parts. One section is completely enclosed and has a floor area of 500 sq. ft. In this portion, 200 adult hens are

[1] Accepted for publication March 2, 1959.

housed in 80 linear feet of wire cages, two- and 8-bird units. Cockerels were released and allowed to run free on the floor of this part of the building.

The part of the building used for the untreated check is smaller; there are 7 wire cages each with 3 or 4 adult roosters at all times. Each of the cages has a floor area of 9 sq. ft.

Cockerels were obtained at a hatchery following separation of the chicks by sex; we took the cockerels because they were surplus. The cockerel chicks were brooded for 2 weeks and then released under the wire cages at a ratio of one chick on the floor to 10 hens in the cages.

At the start of the experiment the manure was cleaned up completely in both parts of the building. The next day a total of 1000 to 1500 eggs of the house fly (*Musca domestica* (L.)), obtained from one of the laboratory colonies of our department, were put on the wet spots of the droppings in both parts of the building; then the cockerels were released in the treatment area. Thereafter, fly eggs were planted in the manure 2 or 3 times each week during the course of the study.

Fly larvae were counted in the areas where the manure was wet. A standard 1-pound scoop was used to collect a sample of wet manure. At each count station the contents of a full scoop were put into 3 quarts of water. stirred vigorously and allowed to settle. All the larvae that floated to the top in 15 seconds were counted.

Fly pupae were counted at stations situated in dry protected areas several feet from wet droppings. Used feed sacks were folded into a pad approximately 1 square foot in area and laid on a cleanly swept spot. At each count the sack was raised and all the pupae and pupal cases were counted. The area was then swept clean and the sack was put back in place for the next count.

The first counts of larvae and pupae were made in the fourth week; thereafter, counts were made at intervals of 2 or 3 weeks.

Enough water to wet the manure thoroughly was put on the droppings every other day in a deliberate attempt to provide favorable conditions for fly breeding. Frequent turning of the droppings by cockerel scratching in the treated area promoted drying of the manure.

The young birds were given routine inoculations for disease and general care in line with accepted practice. A light portion of scratch and mash was supplied each day at the end of the afternoon. The timing of the feeding kept the birds hungry during the daylight hours and thereby more interested in hunting fly larvae and pupae. The supplemental feed, inoculations for disease and labor to maintain the cockerels averaged 0.25 cents per month per adult hen.

DISCUSSION OF RESULTS.—Results of the study are shown in table 1. The values shown are means of 10 replicates for "treated" and 5 replicates for "untreated check." At the first count, following complete clean up of the manure, no larvae or pupae were found in either the treated or untreated check areas. Thereafter, following initiation of planting fly eggs 2 or 3 times each week, the data of table 1 show a relatively high population of fly larvae and pupae in the manure of the untreated check area in comparison with practically none in the treated area. In the chick-treated area the droppings did not pile up but were scattered and shallow. The almost complete absence of fly larvae and pupae suggests that the chicks quickly search out and eat the larvae and perhaps even the eggs.

On the 8th, 10th, 18th and 20th weeks a few larvae were found in one or two of the manure samples of the treated area. These larvae occurred in spots where the manure was very wet and hard for the chicks to work so piles were starting to impact and grow. By the 15th to the 20th week we noticed that the mass of accumulated droppings directly under the cages began to exceed the ability of the chicks to turn it effectively. However, the pupal count in the treated area remained at zero; no pupae were ever observed at any time in the manure or surrounding borders of the treated area. This suggests that the larvae the chicks did not find in the manure were caught as they left the wet parts of the manure to seek a dry environment to pupate. At the 26th week (6 months) the manure was cleaned up and removed from both areas of the building.

Table 1.—Control of house fly larvae and pupae in the manure of poultry on wire using 1 cockerel on the floor to each 10 hens in the cages.

WEEKS	TREATED		UNTREATED CHECK	
	Larvae	Pupae	Larvae	Pupae
0	0	0	0	0
4	0	0	110	26
6	0	0	148	91
8	3[a]	0	205	98
10	1	0	55	91
12	0	0	200	79
15	0	0	43	72
18	0.2	0	25	30
20	19	0	365	571
22	0	0	130	700
24	0	0	29	378
26	0	0	151	199

[a] These and all subsequent larvae were found sheltered deep in 3 to 6 inches of impacted manure.

When the cockerels were 13 weeks old they were replaced with young chicks. In the laboratory no particular disadvantages were found to the ratio of one cockerel to 10 hens. However, conditions for flies are rarely as good at commercial poultry ranches as were created in our poultry house, and it is probable that under good management practices the number of hens in cages per cockerel on the ground can be increased considerably, or a decrease in the ratio of cockerels to hens.

The results of the experiment indicated further trials of the method. Experiments are now in progress at three commercial poultry ranches and a dairy.

The Infective Index of the Spined Rat Louse, *Polyplax spinulosa* (Burmeister), in the Transmission of *Haemobartonella muris* (Mayer) of Rats[1]

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The spined rat louse, *Polyplax spinulosa* (Burmeister), transmits *Haemobartonella muris* (Mayer) when the rat ruptures infected lice and inoculates itself by scratching and biting (Crystal 1958). *H. muris* does not provoke disease in normal adult albino rats. However, following partial blockage of the reticuloendothelial system, such as by splenectomy, a severe anemia occurs and often proves fatal.

Mayer (1928) was able to transmit the disease in each of 4 cases with about 30 infected lice. Cannon & McClelland (1928, 1929) were successful in each of 6 cases with 12 lice. On 2 occasions, Eliot & Ford (1929) reported 4 lice produced infection while 7 other rats became positive with 10 lice. The work reported herein confirms and extends these observations.

METHODS.—A previous report (Crystal 1956) gives in detail the source and techniques of maintenance of the host, parasite

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Table 1.—Infective index of *Polyplax spinulosa* in transmission of *Haemobartonella muris*.

Number of		
Experimental Rats	Lice Placed on Each Rat	Rats Developing Haemobartonella Anemia
2	48 or 50	2
2	25	1
3	10	2
6	5	4
3	4	1
4	3	2
4	2	0
7	Control	0

and vector as well as the general procedures utilized. Lice were removed from latently infected rats and placed in predetermined numbers on healthy susceptible test animals. The experiments were controlled by rats either untreated or inoculated with physiological saline. All test animals were splenectomized within 2 weeks after infestation with lice. Diagnosis of haemobartonellosis was made by the examination of their tail bloods daily for at least 15 days. Enumeration of erythrocytes and estimation of the hemoglobin content served as indices of the existence and degree of anemia. Giemsa-stained blood films were examined microscopically to detect the presence of *H. muris*.

RESULTS.—The data in table 1 show the number of presumably infected lice placed on each rat and the number of rats which developed the haemobartonella anemia following splenectomy. It is noted that the transmission of *H. muris* from a latently infected rat to a healthy one succeeded with as few as three lice.

DISCUSSION.—The results obtained are consistent with the role of *P. spinulosa* as a permanent, obligatory ectoparasite. When the lice of a carrier rat imbibe blood, they are simultaneously exposed to infection with *H. muris*. It should be expected that a high percentage of the vectors would become infected under these conditions. Only 72% of the lice used in these experiments resulted in successful transmissions. It is reasonable to conclude that a smaller percentage of lice was infected and a still smaller percentage infective. The experiments reveal that not every louse which feeds on a latently infected rat becomes infected. This is probably due to the relatively low infectivity of carrier blood in which *H. muris* is present in very small numbers.

REFERENCES CITED

Cannon, P. R., and P. H. McClelland. 1928. Rôle of ectoparasites in bartonella infection of albino rats. Proc. Soc. Exptl. Biol. and Med. **26**(2): 157–8.

Cannon, P. R., and P. H. McClelland. 1929. The transmission of bartonella infection in albino rats. Jour. Infect. Dis. **44**(1): 56–61.

Crystal, M. M. 1956. A study of the mechanism of transmission of *Haemobartonella muris* (Mayer) of rats by the spined rat louse, *Polyplax spinulosa* (Burmeister). Dissertation deposited in the University of California library, Berkeley. 79 pp.

Crystal, M. M. 1958. The mechanism of transmission of *Haemobartonella muris* (Mayer) of rats by the spined rat louse, *Polypax spinulosa* (Burmeister). Jour. Parasitol. **44**(6): 603–6.

Eliot, Calista P., and W. W. Ford. 1929. Further observations on the virus of rat anemia with special reference to its transmission by the rat louse, *Polyplax spinulosa*. Amer. Jour. Hyg. **10**(3): 635–42.

Mayer, M. 1928. Die Übertragungsweise der infektiösen Rattenanämie. Klin. Wochenschr. **7**(50): 2390–1.

German Cockroach Resistance Tests in the Panama Canal Zone[1]

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The German cockroach, *Blattella germanica* (L.), has become increasingly difficult to control on Army posts in the Canal Zone area employing the standard supply item 2% chlordane in kerosene solution. Poor control of the cockroaches with the chlordane residual has been particularly noticeable in Army kitchens and mess halls, exchange facility restaurants, and about the display and checkout stands of Army commissaries within the command. From 1950 on many Army food handling installations have been more or less routinely treated with chlordane in kerosene residual sprays and dusts in cracks, wall surfaces and electrical apparatus. Since the latter part of 1956 effective control, based upon a 60-day interval between sprayings, has become unsatisfactory in many of the locations and resistance to chlordane was suspected as a principal factor in the poor control being experienced.

In order to confirm suspected resistance of the German cockroach, two collections of about 75 to 100 adult insects were made during the early part of February 1958 in the Corozal Commissary sales store and the Curundu Post Exchange restaurant. The two colonies were raised in the insectary of the Preventive Medicine and Malaria Control Unit at Corozal in round three gallon, open top, glass jars covered with fine cloth mesh to prevent the escape of the insects. The basic ration for the cockroaches consisted of a balanced, dry kibbled dog biscuit to which was added Pablum baby cereal. Water was always available and fresh cut apple sections offered periodically when available. As the F_2 and F_3 generations appeared, each colony was divided into two additional containers to prevent overcrowding.

METHOD.—Test procedure involved exposure of adult male cockroaches to deposits of chlordane and malathion at 10 mg./sq. ft. and lindane at 5 mg./sq. ft. following the method of Keller *et al.* (1956). After dilution of the ESA test grade insecticides with acetone, required quantities of the dilute solutions were swirled about in 1-pint widemouthed Mason jars until the solvent evaporated to leave a residual deposit on the bottom and sides of the test containers. The test jars were treated 18 hours prior to introduction of the cockroaches.

Cockroaches were immobilized and sexed by employing carbon dioxide gas as an anesthetic and 10 individuals put directly into the replicated test jars while still anesthetized. Temperatures ranged from approximately 75° to 90° F.; relative humidity from 70% to 95% during the test periods. Cockroaches were considered dead when they were knocked down and could no longer perform coordinated locomotory actions. At the end of 24 hours exposure a piece of cut fresh potato was given to all replicates remaining in test and to all control jars.

To arrive at the estimated LT-50 the mean per cent mortality of the three replicates for each of the colonies at the various observation intervals was converted into mortality probits after Bliss (1935). The probit values were plotted on three cycle semilogarithmic paper, straight lines fitted by eye, and the estimated LT-50's read directly from the regression lines. There was no control mortality.

RESULTS.—Estimated LT-50's obtained in these experiments for chlordane and lindane are compared with those of Keller *et al.* (1956) and malathion with the LT-50 published in AFPCB Technical Information Memorandum Number 3 (1959) in table 1. The resistance to chlordane and lindane appears to be considerable in the Curundu strain, with a lesser degree of resistance being evidenced in the Corozal strain. Malathion resistance in both strains fell within the range exhibited by the normal U. S. strain.

The wide disparity in estimated LT-50 between Corozal and Curundu strains may be related to previous insecticide usage at these two locations. Chlordane had been used continuously in

[1] Accepted for publication March 13, 1959. Partial cost of publication of this paper was met by the author.

Table 1.—Comparison of estimated LT-50 values obtained in the Canal Zone and colonies of German cockroaches previously tested in the United States.

COLONY	DATE	LT-50 VALUES IN HOURS		
		Chlordane	Lindane	Malathion
Curundu, C.Z.	May 22	>47	3.4	2.1
Curundu, C.Z.	June 18	46	3.7	1.1
Corozal, C.Z.	May 22	17	1.5	
Corozal, C.Z.	June 18	5.9		1.8
Normal, U. S.		3.2	<0.5	2.0
NPCA Res., U. S.		18.5	1.3	
Ft. Sam Houston, U. S.		12	0.7	

the Curundu restaurant from 1950 to early 1956, In the Corozal commissary, chlordane had been used from 1949 to 1954, with DDT being employed from the latter date until early 1958. The selective pressure of chlordane on the Curundu strain has thus been more continuous and may account for the difference in resistance to this insecticide exhibited between the Curundu and Corozal strains. No explanation is advanced for the apparent loss of resistance to chlordane in both strains between the May and June tests.

REFERENCES CITED

Armed Forces Pest Control Board Technical Information Memorandum No. 3. Methods for determining resistance of insects to insecticides. January 30, 1959: 20–26.

Bliss, C. I. 1935. Probit method for dosage—mortality curve. Ann. Appl. Biol. **22**: 134–67.

Keller, J. C., P. H. Clark, C. S. Lofgren and H. G. Wilson. 1956. Results of USDA-Sponsored research tests on cockroach control. Pest Control **24**(9): 12–20.

BOOK REVIEW

THE PRINCIPLES OF BIOLOGICAL CONTROL. By HARVEY L. SWEETMAN, Wm. C. Brown Company, Dubuque, Iowa. Lithoprinted, 8.5″×11″, xii+560 pages, 382 figures. 1958. Price $8.75.

The new edition of Professor Sweetman's book has been largely revised and expanded, running to more than 2½ times the number of words of the previous work, but remains fundamentally the same book, with the same basic plan and objectives.

In attempting to cover all facets of the rather loosely defined subject of biological control in a single volume, Professor Sweetman has undertaken an ambitious task, and on the whole has done it well. There are obvious limitations to what can be included in a book of this scope and size, and his selection is bound to meet some criticism. While few of the sections will be considered complete by specialists in the various fields, such completeness is not a necessary feature of the book. The principal methods by which biotic agents have been used or suggested for use, and the principal organisms concerned, are discussed with examples.

Included are a number of marginal organisms of possible use in biological control, such as nematodes, some crustacea, some microorganisms, mites, spiders, and a large number of insects which are polyphagous in the widest sense. While one is happy to see these organisms included, Professor Sweetman is apparently less at home with these groups than with the parasitic hymenoptera and diptera. Some of these groups are discussed so briefly that their inclusion is but a token recognition of their existence. Of the spiders, for instance, the remarks that 'the group warrants further study," though the group has received, and is receiving much more attention than he indicates.

Throughout most of the book there is a lack of critical analyses of methods that have been used and work that has been done and thus the uninitiated student may gain the impression that biological control is a much more precise art than is the case. In Chapter XIV it is anticlimatic to find that in spite of the prodigious efforts indicated in the earlier chapters, Professor Sweetman feels that only 80 cases of "successful" biological control can be cited for the entire world.

This raises the subject of what constitutes successful biological control. It is always difficult to relate cause and effect in regard to changes of population numbers, and this is especially difficult in the case of biological control projects in which, because of the lack of adequate experimental controls, it is often impossible to prove that an observed effect results from an applied measure or from other uncontrolled and largely unknown factors. This difficulty is intensified when we cannot even define the effect we are looking for, but which we usually designate loosely as "control." Professor Sweetman, like most of us, uses this word freely but, although he spends some time discussing what is meant by this ephemeral term, he never quite succeeds in defining it. Consequently, neither he nor we are ever very sure what we are talking about when we mention control, and this often leads to somewhat misleading concepts.

The title of the book is "The Principles of Biological Control." Surely the principles of biological control are based on the mechanisms which regulate the numbers of organismic populations. Populations of all organisms must obviously be regulated at some level or other at all times; if they were not their numbers would either expand indefinitely or contract to zero. We must discover the principles governing this natural regulation, and learn to manipulate them to achieve our ends. In this book, however, the author virtually ignores these foundations of his subject, and gives only a superficial treatment to philosophical concepts upon which his subject must stand.

It is perhaps this lack of consideration of the complexities of population dynamics that leads Professor Sweetman to some rather doubtful conclusions. For instance again and again we find an organism classed as "beneficial" simply because it is a known predator, and therefore kills other organisms, sometimes ones that are occasionally pests. This confuses the fate of individuals with the fate of the population or species to which the individuals belong. The killing of an individual, or even many individuals may have no deleterious effect on the parent population. Indeed, it may have an effect advantageous to that population, allowing it to maintain itself at numbers considerably greater than could otherwise be possible. Thus many of the species designated as beneficial by Sweetman must be accepted as such with scepticism until their mode of predation is determined, and possible regulating methods are demonstrated.

To summarize, the book is a well selected collection of abstracts of papers dealing broadly with the subject of biological control, together with enough exposition to summarize the work that has been done on this subject to date. As such, it is a very useful contribution. While it fails to probe deeply into the cause of things, and is regrettably lacking in a philosophic theme, it will provide the student with a valuable introduction into the methods of biological control. To the practitioner of biological control it will also be useful, providing a wide range of experiences and ideas on how certain problems may be dealt with. To the research specialist, however, the volume will be of limited use only, providing at best a rapid access to fields outside his speciality.

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CROP	RATE PER ACRE	INSECTS
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Broccoli, Cabbage, Cauliflower	1 to 3 lbs. as needed	Cabbage looper, imported cabbage worm, diamondback moth
Cotton	2 to 6 lbs. as needed	Cotton leaf perforator, cotton leaf roller, cabbage looper, cotton bollworm
Lettuce, Spinach	1 to 3 lbs. as needed	Cabbage looper
Tobacco	1 to 2 lbs. as needed	Tobacco hornworm
Tomatoes	1 to 3 lbs. as needed	Tomato hornworm

Other crops and insects will be added as experimental results indicate.

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